CAREERS IN SCIENCE

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CAREERS IN SCIENCE

by

Philip Pollack

IN COLLABORATION WITH
VOCATIONAL GUIDANCE RESEARCH
EVELYN STEELE, DIRECTOR

ILLUSTRATED

Introduction by H. C. MADSEN, *Manager,*
Technical Employment and Training,
Westinghouse Electric & Manufacturing Company

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To My Son,

ROBERT POLLACK

Introduction

by H. C. MADSEN
Manager, Technical Employment and Training
Westinghouse Electric & Manufacturing Company

INDUSTRY needs scientists. It needs them now to create and perfect materials and equipment for use in winning the war. As the war approaches an end, and afterwards, it will need them to develop new products so that employment and an improved standard of living may be enjoyed by all. The work of the scientist has enabled American industry to achieve the position of leadership it holds today and, equally important, it will make possible continued leadership in the future.

The young man or woman starting out in a scientific field should realize that many years of painstaking effort must be put into the work before results of any major importance can be expected. The college years as well as the early years of employment can be considered prerequisites for later success. Fortunately, young people have the energy and the imagination to see them through periods that might otherwise prove discouraging. I recall a motto that hung on the wall of our eighth grade classroom. Its message seems especially appropriate in this discussion of youth's opportunities in the scientific fields.

> Let Youth help shape the World while the
> Vision Splendid is still before its eyes.

It is that vision that enables the scientist to perform the miracles he does, that vision plus a lot of hard work.

The fields of science are many, as you will realize from reading the chapters of this book. In order to determine one's

proper field, much thought should be given to a self-evaluation early in the training period. Good standardized tests are available which, when coupled with expert counseling, can help the student discover the field or fields for which he is apparently best suited. I stress this point because too many young men and women prepare themselves for a field not consistent with their greatest abilities or their genuine interests. Find out as early as possible what type of work you would enjoy doing the rest of your life.

The young scientist who enters industry is looking for certain definite things from his work and from his company. He wants the personal satisfaction which comes from contributing something original to the fund of knowledge already accumulated on a subject. He wants to become outstanding in his field. He wants security in his job. He wants an opportunity to advance to more important work if he proves equal to the responsibilities of the job ahead. He wants favorable working conditions and appreciative supervision. He wants an equitable salary for the work he performs.

His company, on the other hand, expects certain things from him. A good fundamental training is only the beginning. He must continue to grow by keeping abreast of new developments in his field. He must show initiative and be thorough in his work. A willingness to shoulder new responsibilities and to do a little more than is expected distinguishes the superior worker from the ordinary. Loyalty to his company and to his superiors is second only to loyalty to himself and to his personal ideals.

The scientist must render unto others the highest type of service of which he is capable. He may expect returns commensurate with the services he performs. He must maintain, or improve, the reputation of his profession through the proper application of his talents.

The scientist as a public citizen is in a unique position. He

brings to his community and to his nation an understanding of natural and physical phenomena which can have a profound effect on matters normally thought of as humanistic or social. His methodical and thorough approach to problems furnishes a balance for those who, because of different training, may be prone to act without a complete appraisal of the facts. In thus taking part in outside activities he leads a fuller life himself and he renders an important service to his fellow men.

From men of such outstanding traits are the future managers of large enterprises chosen. Industry must look to its young people for tomorrow's leadership. In studying the men constituting top management of one of our large industrial companies, it was found that most of them had started out as young scientists or engineers some twenty or more years before. They earned the right to represent their company in positions of responsibility, and they worked unceasingly at the job of improving themselves for the job that lay ahead. The particular field in which they had studied as undergraduates seemed to be of minor significance. Common to all was an enthusiasm for their work and a desire to excel in whatever responsibility was theirs at the time.

Women, as well as men, are finding great opportunity to render vital service to their country today. There is every reason to believe that the future will present even greater opportunities for them in the scientific fields. By virtue of their temperament, women are capable of the exacting requirements of laboratory work. Special training programs undertaken by industry during the war period have proved that women have the interest and ability to do advanced technical work.

As you consider the fields of science, remember that a career in any one of them is a challenge to one's imagination and energies. Even greater things remain to be accomplished

than have been accomplished in the past. Science is a living thing. Its potentialities are unlimited. Its results are important only as they make possible better living and greater enjoyment for all.

Pittsburgh, Pennsylvania

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CAREERS IN SCIENCE

Chapter I

SCIENCE CREATES NEW WORLDS AND CAREERS

THE surprising thing about the age in which you live is not so much the marvels of science as the fact that you take them as a matter of course. The household magic of oil burning furnaces, tungsten filament lamps, radio and telephone are commonplace in your daily life. You accept them unthinkingly as if they had existed for ages.

Look at the clothes you put on so sleepily this morning: they were woven by giant power looms and dyed by coal-tar extracts. Perhaps you used an electric shaver which was not even dreamed of by your grandfather as he coped with a straight razor and soap. As you put on the neatly mounted glasses that correct your astigmatism, it did not occur to you that this eye defect was not even known to exist before 1801.

Coming home from work, you may ride in the subway, unconscious of the fact that, to make your trip possible, rectifiers are converting alternating currents into direct currents while magic transformers are reducing 13,200 volts of electricity to 600 volts on the rails. Later, you drop into a movie theatre. Watching and listening to a technicolor talking film, you are so absorbed that it never crosses your mind that the first public exhibition of flickering pictures (the crude forerunner of the silent films) took place only fifty years ago in a reconverted shoe store in New York City.

The "simple" things you do and see and listen to so casually would have startled the most enlightened citizen of 1840. Yet you do not thrill to the wonder of it all, for these inventions and appliances have long been part of your daily life.

This is an age of science, you will say. But do you realize just how much you owe to this twentieth century magic?

Science keeps you alive when you are born; grows health-giving food and transports it to your table; clothes you; heals you when you are ill; keeps you informed through radio, pictures and the printed word of what is happening in the farthest corners of the earth; transports you safely across land and water by rail, air, and steamship. Science enriches your life with comforts and conveniences. It creates more leisure, so that the ten and twelve hour working day of a century ago is reduced to eight hours and less. It has increased the average life expectancy from twenty-five years, as it is in some parts of India today, to sixty-five in the United States.

Science has practically abolished certain diseases that threatened to destroy a large part of the human race; it is reducing deaths from other diseases. Science, applied to the human mind (psychiatry), enables you to understand yourself more clearly and helps to free you from fears and anxieties. Science has flashed bright beams on the past history of the earth and of the human race; it has cracked open the infinitely small, submicroscopic world, on the one hand, and the infinitely vast universe of constellations and galaxies on the other.

These accomplishments and many, many others are rightly attributed to science. But "science" is a bloodless word. It is not science, really, but scientists – a vast army of them – who are responsible. These are the people who, by their collective achievements, designed the modern world.

They also created a new profession that was unknown two hundred years ago: the career of science.

It is difficult for you to realize how new this profession is. Imagine yourself living in the United States in 1840. At that time, this was mainly an agricultural country. If you were deciding on a career, your choice would have been confined

to one of the following occupations: medicine, law, bookkeeping, farming, the ministry, teaching, fishing, or manufacturing. The most important industries were textile and shipping. Manufacturing required little machinery and was small-scale. And careers in science as we understand the term today, were nonexistent.

Indeed, scientists were regarded as slightly balmy folk who could not be entrusted with practical matters. Important discoveries were quite often stumbled upon by amateurs with little specialized training. For the most part they were similar to "scientists" of previous generations, like the barber Arkwright, who invented the spinning jenny, or the ex-clergyman, Cartwright, who devised the first power loom. Typical of his age was Charles Goodyear, who discovered the vulcanization of rubber by sheer accident. Stressing the need for a thorough scientific education, an authority wrote many years later: "To the trained physicist and chemist, we must look for the startling inventions of the future, rather than the illiterate Arkwright, the inspirational Cartwright, or the self-taught Goodyear."

The lack of such scientific education in 1840 is underscored by the fact that facilities for scientific training hardly existed in the United States at that time! Although the rudiments of the subject were taught in a few small schools, so undeveloped was the scientific profession that you probably would have gone to a European university to obtain training in chemistry, physics, or biology. It was not until 1847 that the first school of science in this country was established at Harvard University. As one thinks of the scores of scientific schools and colleges that are available today, in medicine, engineering, geology, agriculture, chemistry, etc., one gets a glimpse of the great stride that science has made in a single century. Only after the Civil War did the application of scientific inventions and discoveries to industry lead to

large scale manufacturing. This created a growing need for physicists, chemists and biologists as well as engineers and executives, not only to direct operations and processes, but also to develop improvements and cheaper methods of manufacture. Women, too, were affected by the industrial revolution, and some were attracted to the new scientific professions.

These professions grew amazingly in scope and complexity, keeping pace with the colossal growth of industry in a machine age. Hardly in existence a century ago, they have expanded to such proportions that the majority of careers open today are either in the field of science or related to it.

The field of science has four main divisions: chemistry, physics, biology and geology. It would be impossible to even list the various jobs based on training in these subjects, they are so numerous. There are scientific jobs for many types of people from the gadget-minded to the formula-minded. Some work with test tubes and chemicals; others with gauges and electrical machines. Some stab guinea pigs with hypodermic needles filled with drugs; or fight forest fires; or plant seeds in chemically treated soil. Others record ground elevation through surveyor's instruments; or explore oil fields; or study the movements of planets through giant telescopes or the behavior of bacteria through ultraviolet microscopes.

The materials and instruments used by scientists may differ, but their attitude and approach are the same. Chemists, physicists, biologists, geologists all perform experiments to test theories and discover natural laws and apply them for the benefit of mankind. Scientists are the most inquisitive people in the world, forever seeking Nature's close-guarded secrets.

Many people still think of scientists exclusively as inventors and engineers, poring over mechanical blueprints and practical, money-making gadgets. There is no denying the great importance of inventors and their contributions to industry.

It is equally important to realize, however, that their machines and gadgets are based on the theories and discoveries of laws in nature made by men who were too excited investigating the reasons for things to bother about practical applications of their theories. These men and women are no longer scoffed at as ineffectual dreamers. Too many scientific dreams have created dividends for stockholders.

Consider the electrical industry in this respect. A colossal enterprise employing, directly and indirectly, 6,000,000 workers in the United States, this industry was born out of the "impractical" theory of electromagnetic induction formulated by a nineteenth century theorist, Faraday! Then there was James Maxwell who spent years scrawling mathematical symbols on paper before announcing that electromagnetic waves, a new kind of radiation, must exist because his mathematical calculations proved it! They were later detected for the first time in the laboratory by Hertz, another "impractical" scientist. What good was the discovery? Nobody knew, until Marconi made use of it to invent wireless telegraphy, one of the most important inventions of modern times.

The chemical industry is another example. Research chemists spent years investigating the structure of carbon compounds in laboratory experiments. Their research involved mathematical analysis of molecular theory and what, on the face of it, could be more useless from the viewpoint of industry? Yet out of their research grew one of the most amazing developments of modern chemistry: the extraction of dyes, high explosives, antiseptics, perfumes and medicines from coal tar!

The birth of a great industry, the manufacture of paper from wood cellulose, emanated from the scientific "dreaming" of Reaumur. While he was studying the habits of wasps, he would have been startled if you had interrupted his re-

search to ask him what practical value it had. Yet his observations and discoveries as to the manner in which wasps constructed their paperlike nests from substances created by the mastication of bits of wood, was largely responsible for the start of this industry.

It is no wonder that industrialists are today hiring men of theory, as well as engineers, to do their "dreaming" in industrial research laboratories.

The field of medicine has been greatly benefited by pure research. In 1908, an Austrian scholar named Gelmo, discovered a new chemical compound which he described in his doctorate thesis for the University of Vienna. Next year, chemists experimented with it in their attempts to improve the utility of dyes. It was not until 1919 that two German doctors discovered that the chemical kills bacteria. The name of the chemical is sulfanilamide, the famous drug that has saved millions of lives. Thus, one of the most important medical discoveries of the century was the result of theoretical chemical research.

The importance of pure research to industry and ultimately to human welfare is obvious. This is not to disparage the work of the applied scientist. A Faraday is necessary; so is an Edison. The point to remember is that the battle for recognition by research scientists who can promise no immediate material benefits from their research, is practically won. The size of research budgets illustrates this point very well. According to the National Resources Planning Board, the United States has been spending about $300,000,000 a year on research of all kinds and employs over 70,000 workers in research laboratories.

If you are interested in pure research, it might be wise for you to work toward a career in science teaching. Many research men and women occupy faculty positions simultaneously with the carrying on of research experiments. Impor-

tant discoveries have been made in the laboratories of universities. Teaching will deepen your understanding of your field. In addition, by winning academic honors, you will better your opportunity to be chosen for an important post in a research department of private industry. Many top men in industrial science have taken this path. Consider Dr. Howard E. Fritz, for example, one of the best known technical men in the rubber industry. As director of B. F. Goodrich research, Dr. Fritz has the responsibility of one of the largest technical and laboratory groups in the rubber industry. He came to B. F. Goodrich from the engineering school faculty of Ohio State University, starting with the company as manager of a small department.

A career in science teaching might eventually lead you into scientific writing. You would be a reporter of the most exciting spot news of the century, – scientific discoveries and developments. Several science writers started their careers as teachers. Bernard Jaffe, for example, teacher of science in a Brooklyn, New York high school, won a prize for his first book called *Crucibles*. He has written several other books since, his latest being, *Men of Science in America*. You might become a science editor like David Dietz of the Scripps-Howard Syndicate, which once sent Dietz to Liverpool to report the meeting of the British Association for the Advancement of Science.

Reflecting the spirit of the times, science-writing has become a new trend in journalism, occupying considerable space in the "quality" magazines. It is much better paying as a career than teaching, although opportunities are limited. There are other fields that engage people interested in theoretical aspects: museums and institutes need scientists on their staffs, for education and research. This may involve expeditions into the interiors of primitive countries as well as planning of educational exhibits.

Job opportunities are the most plentiful in practical or applied science. With expansion programs already planned in agriculture, public health, forestry, medicine, chemistry and aviation, the demand for scientists promises to be greater than ever after the war. One civil engineering program, for example, is the proposed expansion of the water supply system in New York City. It will be constructed to take care of an increase in population from 7,500,000 to 25,000,000. New or expanded power plants, highways and railroads are in the blueprint stage in every state of the Union. The "welcome" banner is flying for thousands of new scientists whose skill will be challenged by the new projects. Those with unusual abilities will win positions of leadership. But even lesser talents will be needed to fill the thousand and one positions necessary.

As any branch of science develops, it gives birth to new specialties which in turn are subdivided into smaller divisions of study. The divisions of chemistry alone are already so complicated that they include every phase of life and industry. The American Chemical Society breaks chemistry down into the following divisions:

(1) agricultural and food chemistry
(2) biological chemistry
(3) cellulose
(4) dyes
(5) fertilizers
(6) gas and fuel
(7) industrial and engineering chemistry
(8) leather and gelatin
(9) medicinal products
(10) organic chemistry

(11) paint and varnish
(12) petroleum
(13) physical and inorganic chemistry
(14) rubber
(15) sugar
(16) water, sewerage and sanitation

Almost every one of these divisions is in a process of exciting development. Many are active in the search for artificial raw materials to take the place of natural materials that cannot be obtained in sufficient quantities. Discoveries partly stimulated by war needs have already resulted in substitutes for natural rubber, cotton, oil, fertilizer, leather – yes, even food itself in some cases. The natural source of leather is the hide of cattle. But if world industry had to depend on cattle for the leather it needs each year, so many herds would have to be raised that the grazing grounds needed to feed them would equal in area all the states west of the Mississippi. Artificial leather has thus become a necessity; like synthetic rubber, it is here to stay.

The search for substitutes has led to discoveries that have widened the boundaries and possibilities of science. What chemistry has done to agriculture, for example, is like a story out of Jules Verne. If a magician were to transform a bottle of milk into a suit of clothes, he would not be doing anything more startling than science has already performed in this direction. More and more, farm crops are being raised for industrial use. Sugar from sawdust, varnish from peanuts and rubber from dandelions are not dreams but realities. Freed from dependence on foreign countries for raw materials like natural rubber and silk, industry, according to many authori-

ties, will absorb the new plastic products at an ever faster pace. This means more research, more laboratories, and more jobs and careers for scientists, as manufacturers seek higher quality products and cheaper methods of production. Increasing the output of power generators and discovering new power sources are other major problems that open up limitless perspectives. Coal reserves in the United States are sufficient for normal demand, but will not last forever and are slowly being exhausted. In the last ten years, the amount of coal consumed has doubled. Industry and transportation are at the mercy of dislocations in the schedules of coal production and delivery. Clearly, power is a serious problem when coal is king. What can be done? Two things: first, electrical output can be stepped up in the power plants. Second, new sources of power can be developed, like the sun — a process still in its experimental stages.

Research scientists of Westinghouse Electric and Manufacturing Company have already succeeded in producing 396,000 volts of electricity from 500 ton generators in their high power laboratory. Mechanical energy is supplied by 300 ton rotators and the momentum of their movement in the operation is so great that it takes 2½ hours for them to coast to a full stop after the discharge. This laboratory is a microcosm of the world of science. At strategic points are 10 photo cells. If a short circuit develops, these cells, or electric eyes as they are called, "see" it and relay a message automatically to switches that disconnect the transmission. Behind these operations is an army of physicists, chemists, geologists, and even biologists, experimenting, designing, recording chemical reactions, drawing blueprints, analyzing samples, studying formulae. When you witness the two men in the control room operating the generators and giving orders through telephones that connect the control room with the power house, much as a sea captain controls his ship

from the bridge, you realize anew how efficiently scientists have harnessed the forces of nature.

Perhaps you think that successful careers in science are only for extraordinary intellects. Certainly, top flight positions in any field will be won by people of unusual abilities. But one of the advantages of science is that it affords opportunities for every graduate of ability from the average to the highest. You need not be an Einstein to qualify for physics. Nor do celebrated names dominate the field. Sheer ability is the only test of recognition. Mistakes and overlooked opportunities are not the peculiar property of ordinary folk. Even famous scientists may be guilty of lapses and the door is always open for an unknown, young scientist, like yourself, to notice the discrepancy and make a name for himself with a new discovery. Science knows no favoritism. It is one of the most democratic of callings.

Consider the discovery of the X-ray, which stared Sir William Crookes in the face one day in his laboratory. Careful physicist though he was, he failed to observe it. What happened? He had sent a current through a vacuum tube and noticed that photographic plates in the room became fogged, even though the box containing them was wrapped. Only when he removed the plates from the laboratory, did the mist disappear. Ironically, he made a mental note to keep them out of the laboratory when the vacuum tube was in operation. This might be called "caution without curiosity." A few years later, Wilhelm Konrad Roentgen, a German professor, noticed the same phenomenon. Not satisfied with merely protecting his photographic plates, he asked himself the crucial question: Why? Investigating, he discovered that the fogging started as soon as a mysterious green glow (that Sir Crookes had also observed) appeared in the tube. It was not long before he discovered that the fog was caused by a new type of radiation coming from the glass walls of the tube

and passing through the wrapping and box of the photographic plates. That is how the X-ray was discovered.

It was not superior scientific ability but more perhaps of the common garden variety trait of curiosity that led to the discovery; the same curiosity that makes a child take a clock apart to find out what makes it tick; the curiosity of Watt, when he observed steam shooting from a kettle spout and wondered if it was powerful enough to push a piston. It is this kind of curiosity and the willingness to work hard to satisfy it, that drives scientists forward to investigate and experiment unceasingly. Have you this kind of curiosity?

Every year in normal times 3,500,000 young men and women graduate from high school in the United States. Many of them choose branches of science as their future career. Many will make their choice because of an interest in a particular field. A few may be influenced mainly by a desire to make a fortune. If you are one of the latter, a word of discouragement: it is easier for a camel to pass through the eye of a needle than for a scientist to become rich in his profession. There is ample compensation, but it is not in dollars and cents. You must find it in the work itself, no matter how long and arduous, in the excitement that comes from pioneering and creating a new theory, system, or machine, in the realization that you are adding to progress. Few chemists, physicists, laboratory research men have ever become wealthy, even after they reach the pinnacle. In general, an income of $3,500 a year is regarded as an excellent income in any field of scientific work and you must serve your apprenticeship at a much lower figure for a long time, whether you are a chemist, forest ranger, meteorologist, or medical research man.

These are the conditions. Are you willing to accept them? Have you got what it takes? These are the important questions for anyone considering a career in science.

Chapter II

THE PRICE OF ADMISSION

William A. Hayes, young Westinghouse electronics engineer, became famous overnight because he thought of spaghetti!

It was not that Hayes was hungry. On the contrary, he was too absorbed with the problem of breaking the bottleneck in the production of electron tubes to even think about food. Hayes was watching workers insert nails inside the coiled up wire filaments welded to the tube mechanism. The nail supported the coil and kept it in accurate alignment. Fine! But it was difficult to remove and took up five minutes of precious time for each tube.

Five minutes! No wonder there was a bottleneck and war orders were held up. Hayes pondered the problem. Suddenly his eyes lighted up. Spaghetti! There's the answer, perhaps! Spaghetti instead of nails. After the welding, it could be burned out in a flash. Why not try it?

But wait, the young engineer said to himself. Maybe it wouldn't be practical. He knitted his brows. Could a stick of spaghetti be cut according to exact requirements? Was it strong enough or would it be too brittle? Could it be machined on a lathe?

He went to work and experimented. He put a stick of spaghetti on a lathe and found he could machine it to the correct diameter. He tested it for strength; it was adequate. Result: the bottleneck was broken and Westinghouse is using spaghetti as a permanent technique of manufacture!

Here, in its simplest form, is the way the mind of the scientist operates. Notice the steps in the mental process

that Hayes took to come to his successful conclusion:

(1) Hayes first studied the problem in all its details. He probably did not think of the nails at first. It could have been some other phase in the manufacture of the tubes that was responsible for the trouble. Only after careful study of the problem as a whole did he come to the conclusion that it was the nails that represented the bottleneck.

(2) Having isolated the obstacle, Hayes set out to overcome it. This required the use of his imagination: if not nails, what else? Maybe it was the actual sight of spaghetti in an Italian restaurant that gave him the idea or maybe he just thought about it. At any rate, the exercise of imagination gave him a possible answer to the problem.

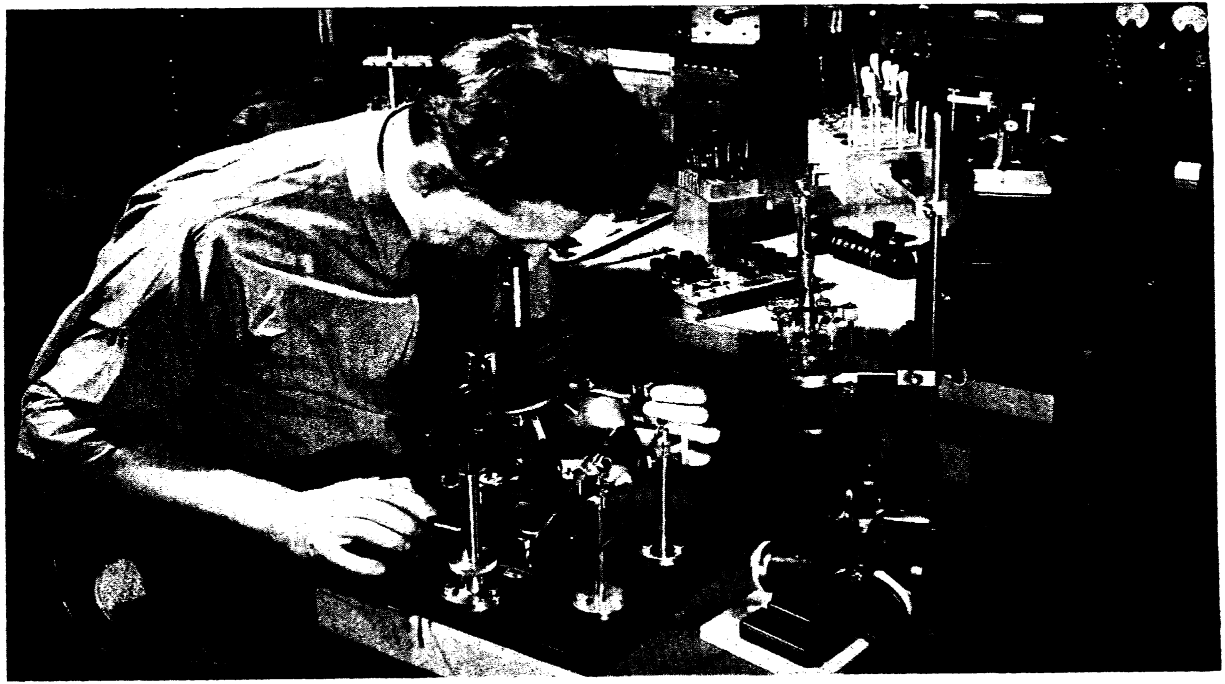
(3) The next step was to find out if this possible solution would work in practice. To discover this, Hayes had to ask himself: what are the actual requirements that the nails meet? He then had to determine if the spaghetti met these requirements. From a theorist, he became a practical technician. He measured the diameter of the nails. Then he tested the spaghetti on a lathe.

What were the chief elements of the scientific mind that Hayes revealed? The ability to study a problem and grasp it in all its essentials; to isolate the cause of the disturbance; to imagine a logical solution and to test the solution thoroughly under rigid conditions.

Hayes' problem was a relatively simple one, but the qualities necessary to solve it are fundamentally the same as those needed for the solution of more complex scientific problems. Other traits are important, depending upon the particular field of work you adopt.

If you are interested in a career in science, you should ask yourself at the very start: Have I these qualities? Can I develop them? Have I got what it takes?

Each career has its own price of admission in special mental



Microanalysis makes accurate examination of very small samples possible. This researcher in Bell Telephone Laboratories conducts microchemical analysis on portable outfit built for field studies. (BELL LABORATORIES — PHOTO BY MORRIS ROSENFELD)



In this large, modern laboratory Dow Chemical Company men are determining composition of chemical compounds. (DOW CHEMICAL COMPANY)



Dr. L. W. Chubb, director of Westinghouse Research Laboratories, demonstrates curious ability of Hipersil, new magnetic material, to carry more "magnetism" in certain paths.

(WESTINGHOUSE)



r. W. D. Coolidge, rector of General Electric Research Laboratories.

(GENERA [illegible])



Transmission engineer at electrical filter, an essential part in multi-channel operation of a toll line.
(BELL TELEPHONE LABORATORIES)



Circuit research engineer examines commercial installation, controlled from Bell Telephone Laboratories, in the American Telephone Company's Long Lines headquarters.
(BELL TELEPHONE LABORATORIES)

and temperamental requirements, whether in science, art, or business. You must face the question boldly; are you willing and able to pay this price?

It is far better to base your decision as to the choice of a career on the answer to this question than to plunge blindly ahead, taking a chance and hoping for "breaks." In the world of science, "breaks" come inevitably, but only to those who have what it takes.

What are the qualities needed for a career in science? Intelligence, of course, but it must be intelligence of a special kind; the power to reason logically on the basis of the observed facts and experimental findings; to reason *objectively*, which means proving, not what you yourself wish to prove, but what the facts themselves point to. Have *you* this type of intelligence or, lacking it, do you think you could develop it?

Patience is also a price. The most exhausting tests must be repeated hundreds, maybe thousands of times. The research scientist cannot afford to be easily satisfied, for the laboratory is no place for people who are sloppy or who want their results in a hurry.

Recently a quarter of a million seeds, representing twenty-four different kinds of vegetables, were planted in one series of experiments conducted by the Du Pont Semesan Laboratories to develop definite answers to important questions about a new fungicide for disinfecting seeds. The research plant pathologists were to determine whether the particular chemical compound under study would give satisfactory results when vegetable seeds were planted within twenty-four hours after being treated; also whether the material would lose its effectiveness or cause injury when treated seeds are stored seven months to a year before planting. The results were entirely satisfactory, but it took a patient study of plants from 250,000 seeds to satisfy the scientists charged with finding the answers.

Paul Erlich named his famous discovery 606 because he had to make that number of tests before he could discover the right combination, in his search for an anti-syphilis treatment. Nor had he any guarantee that he would succeed, or even that he was on the right road. Indeed, in research, most trails lead nowhere, yet must be explored patiently before they are abandoned and another trail taken instead. In practical science like engineering, patience is needed also; the location of oil or mineral deposits by geologists, for example, is a slow and tedious process.

An exact sense of observation is needed. Research work involves the finest measurements to perhaps a millionth of an inch or a ten thousandth of an ounce. The student of science should train his mind and senses to a fine awareness of details. He must detect shades of colors and sounds and be able to recognize the most subtle differences. Modern science has placed at your disposal marvelous electric eye "spotting" machines, but they cannot take the place of the investigator himself, who must make the final decision.

The story is told of a doctor whose success was largely based on this quality of observation. Once he reprimanded a nurse for feeding a child eggs after he had ordered her not to do so. The nurse at first protested her innocence. Finally, she broke down and confessed. When asked how he knew that the child had eaten eggs, the doctor pointed to a minute spot of yellow on the child's bib!

Mental alertness is closely connected with being observant but is not the same thing. Everybody observed steam rising from a heated tea kettle filled with water. Only Watt was alert to the possibility it suggested of the use of steam to move a piston up and down. It is minute differences in bone structure that enable paleontologists to tell one specie of prehistoric animal from another. Certain diseases in plants and animals may be borderline cases that need obser-

vation and mental alertness of a high order to diagnose.

Imagination, too, is part of the price. Great scientists have always been great imaginers; Pasteur imagined the germ theory of disease before attempting to prove it. Astronomers are still checking on eclipses to see whether or not Einstein's theory is correct, for his imagination had leaped ahead of all known facts in his great theory of relativity.

It was imagination and deduction that made a Swiss scientist, back in 1881, conclude that since people, even after eating food that had proper amounts of fats, sugars, proteins and minerals, showed signs of undernourishment, food must also contain "small quantities of unknown substances essential to life." He did not know it then, but he was referring to vitamins, a word that did not come into existence until 1911.

You must have a great capacity for hard work. This need hardly be mentioned, of course, if you are absorbed in your career, but one of the characteristics that differentiates science from other fields of activity is the feverish competition among research scientists to stake claims to discoveries ahead of their colleagues. That is one reason why there have been such great advances in physics, chemistry and biology in recent years; one discovery spurs on another, as all scientists are hot on the trail. It takes the hardest kind of work to buck this kind of intense competition and win recognition, but the success is all the sweeter for this reason.

Patience, exactness, observation, mental alertness, imagination, capacity for hard work — all these are necessary, and something more: you must believe in yourself and in the importance to the world of the work you are doing. If you should feel that what you are seeking is "just a comfortable living" then a career in science is a mistake, as far as you are concerned, and you had better turn to more profitable careers now, while you are young. For the smile on the face of every scientist who has advanced in his profession is the gleam of

enthusiasm for his work. A career in science may not lift you to the upper income brackets, but it can never be boring because science is motivated by endless curiosity about life and the universe and the forces that make and unmake them.

These are the fundamental qualifications for any scientific career. Some of these qualities are innate; others can be acquired with training. Suppose, for example, your habit of observation is dull or sluggish. You can sharpen this sense by making your mind deliberately aware of your surroundings. Try to enumerate from memory all the objects you just saw in a room or in a shop window, for example. See how close you come to the total number. Practice will raise your percentage considerably. Other traits like orderly habits, neatness, etc., can be attained also by training.

While technical training is the basis of a scientific career, knowledge of technique alone in the narrow sense is not sufficient. That is why English composition and literature, as well as analytical geometry are listed as prerequisites in the engineering course. Philosophy and sociology are also important. Knowledge of foreign languages is a "must" for progress in all fields of science is reported each month, in normal times, in the German, French and Spanish scientific magazines. Courses like philosophy and psychology will make you more aware of the significance of your particular section of science while public speaking and composition will enable you to express your ideas more readily and report your discoveries to your colleagues, and to the world at large.

For this reason a thorough, cultural education leading to a degree is advisable before entering any technical school. You should, of course, major in science, but do not feel you are wasting your time by studying literature, philosophy, art, and other cultural subjects. In some schools such as medical school, the number of students admitted is so limited that only those with the highest qualifications are chosen. You would

have little chance of qualifying unless you were a college graduate with a degree. And your cultural background would be an asset in the list of your qualifications.

In choosing your career, it is as important to disregard the wrong advice of well-meaning friends as it is to profit from the experience of others. Many a young man or woman has been dissuaded from entering a career for which he has a secret passion, only to regret it later. In science, every field is as important to the world as any other field and there is only one valid test in choosing your career; ask yourself, not what is the most profitable of professions or the most well thought of by *other* people or the most popular, but: "What would I love most to do?"

Consider, in this connection, the experience of Leland O. Howard. As a young man attending Cornell University, he was "mad" about bugs. He collected and studied them and helped to organize the Ithaca Natural History Society. This was just a hobby, however, and a year after graduation, he matriculated at the College of Physicians and Surgeons, yielding to the arguments of friends who had urged him to study medicine. Still, his secret craving for entomology (the science of insects) simmered within him.

Suddenly he gave up medicine. He took a lowly position in the Entomology Service in Washington, as office assistant. His friends were dismayed. They looked upon "bug study" as a career worthy only of adolescents, for that was the popular conception at that time.

Maybe Howard was assailed by "practical" doubts. Certainly, his new career was not an easy one. Nevertheless, he plugged away at it doggedly. Result: he became one of the world's greatest entomologists and he is largely responsible for the control of insects that have been destroying the nation's food crops and threatening the population with epidemics!

Very often, success in a profession seems to be based on accidental choice, but there is more to it than appears on the surface. Dr. L. W. Chubb, director of the Westinghouse Research Laboratories, for example, was intent on being a surgeon. As a child he decided to follow the career of an uncle whom he revered and who was a physician. While ill in bed, he read a book on the story of electricity. This so fascinated him that he decided to become an electrical engineer.

The important point is not the decision but the fact that he studied electricity with such enthusiasm that, upon graduation, he was asked to stage an electrical demonstration as part of the commencement program. He read books on chemistry so avidly that attending the high school chemistry class was a "waste of time." He converted the attic of his home into a scientific laboratory and spent all his leisure time in experiments. It was not the accident of reading a certain book at a certain age that later made Dr. Chubb one of the outstanding men in radio and electrical engineering, but study and hard work in a field he loved from the start!

Another point to remember: don't let unimportant details deter you from adopting a career that attracts you. Most people, for instance, abhor the evil smelling test tubes of the chemist's laboratory. Yet if you are fascinated by chemistry, these features should not discourage you. As old Johan Joachim Becker wrote way back in 1669 (you can still see these words on the wall of the library of the Chemists Club in New York City):

> The chemists are a strange class of mortals, impelled by an almost insane impulse to seek their pleasure among smoke and vapour, soot and flame, poisons and poverty. Yet among all these evils, I seem to live so sweetly that may I die if I would change places with the Persian king!

One indication of the recognized importance of science is the attempt to select the most promising young men and women of high school age for careers in science. For this purpose, Westinghouse Electric and Manufacturing Company holds an annual nationwide Science Talent Search. The object of this search is to discover these youngsters and help them through scholarships so that their talents and abilities will not be lost to science and industry.

In 1944, forty boys and girls were chosen from among 15,000 entrants representing fifteen states and the District of Columbia. They competed among themselves for $11,000 in scholarships to the best scientific schools. The average age of these boys and girls was sixteen. Each had successfully passed a three hour science aptitude test, in addition to having written an acceptable essay of 1,000 words on *My Scientific Project*, and submitted their school records.

There is little doubt that all of these sixteen-year-olds are qualified for a scientific career. They represent a typical cross section of intelligent American youth. Check their traits and hobbies and enthusiams with your own. This will help you to answer the question: "Am I fitted for a career in science?"

Wildon Fickett, for example, who plans to be a research chemist, began building and assembling his home laboratory on his thirteenth birthday when he invested $10 in chemicals and a simple apparatus. With the addition of a microscope, he set out to prove that stomata (mouth-like openings) exist only on certain parts of leaves. He was going to prove it by taking microscopic photographs. Finding that he needed a two minute exposure because of a poor source of light, he made his own arc light from old dry cell carbons and bits of household electric equipment. When this light proved unsuccessful, he experimented with filters and although he failed, he learned much about light-sources and filters.

You may be under the delusion that it is necessary to develop

a single track mind in order to advance in science. Then the story of Ben Roy Mottelson, age seventeen, will soon open your eyes. He was actively interested in chemistry at high school, looking forward to a research career in chemistry or physics. He was also manager of the track team, president of the mathematics club, vice-president of the French club and a member also of the German club, the debating team and the student council. In addition, he won school letters in cross-country running, football and wrestling! He found time, also, to plan and construct his own equipment for grinding telescope lenses; he ground a six inch lens and mounted it in a telescope of his own construction.

Many of these students are mechanically minded and rig up gadgets and machines in their own attics. Maybe you are not so handy and fear that this disqualifies you from a career in science, though you may be fascinated by scientific theory. Then consider the scholarly, though youthful, Leon William Green. He is interested in mastering the basis of mathematical philosophy. In his essay (for the Science Talent Search contest) on atomic research, he wrote: "My scientific project will fulfill its purpose if I can but help add a rung to the ladder which leads to the explanation of what this building block of the universe is."

Perhaps your special interest is in biology and instead of handling gears and electron tubes, you would like to sow seeds and grow green living things. Then meet Patricia Ann Dunkel who, at seventeen has discovered there can be a lot of fun and excitement in botany, especially when chemicals are added. Her scientific project was chemical gardening. She wanted to control the growth of broccoli plants from seed. Plates, blotters, ammonia and baking powder were some of her experimental tools. She made experiments also with watermelon seeds.

These boys and girls consciously or unconsciously have

followed the advice of Dr. Irving Langmuir, noted scientist, who advised young people in a recent interview: "Train yourselves. Don't wait to be fed knowledge out of a book. Get out and seek it. Make explorations. Do your own research work. Train your hands and your mind. Invent your own problems and solve them."

These recommendations dovetail with the finding of a recent survey which investigated the traits necessary for a career in science as shown by the personal data supplied by scientists in many fields. They are as follows:

1. The capacity to work alone for long periods of time.
2. The ability to take on responsibilities.
3. The ability to keep your head in critical situations that may give rise to fear or panic.
4. The ability to co-operate with other people.
5. A natural interest in the processes of nature.
6. A liking for experimentation out of curiosity.
7. The ability to strike out on your own path of investigation.
8. Methodical habits of studying a problem.
9. The habit of extreme accuracy.
10. The ability to work on very fine details without irritation.
11. The capacity to work on cheerfully even though advancement is slow and recognition tardy.

The somewhat popular conception of the scientist as a bespectacled and academic bookworm is obviously a misconception in relation to these qualifications. "Don't wait to be fed knowledge out of a book," is significant advice. There is nothing dead and academic about science, in spite of the long course of training and education necessary to master it. Science calls for independence of thought and personal initiative; it calls for imagination and eventually striking out on your own and not for blind, mechanical reliance on books and rules.

"Calling all *very* young men!" That this might be the slogan of research science was strikingly brought out recently by a poll that Science Service conducted among a dozen of the leading research laboratories in the country to determine what effect the draft of young men under twenty-six was having on scientific research.

In the research laboratories of the Massachusetts Institute of Technology, Cambridge, Massachusetts, 478 of the technical staff engaged in war research were under twenty-six, and, according to President Karl T. Compton, all of them were irreplaceable. At General Electric Research Laboratories, Schenectady, New York, 29 out of the 145 members of the technical staff were below twenty-six. The director, Dr. W. D. Coolidge, reported that the percentage of young men was highest in new developments like radar. At Westinghouse Research Laboratories, East Pittsburgh, Pennsylvania, fully 32 per cent of the technical staff were under twenty-six.

At the National Bureau of Standards, Washington, D. C., 80 were reported to be from twenty-two to twenty-five years of age. In du Pont's 30 research laboratories scattered throughout the country, about 20 per cent of the technically trained men were under twenty-six and were declared to be "virtually irreplaceable."

About 500 scientists in the Naval Research Laboratory, the Naval Ordnance Laboratory and other Navy research establishments, were under twenty-six. Only the Mayo Clinic reported no draft problem for research workers under this age.

Following is the percentage of scientists and technical workers who are twenty-nine and under, in various fields of science, as reported by the National Roster of Scientific and Specialized Personnel, as of July 1, 1943:

Science	*Number of Personnel*	*Number who are 29 and under*	*Percentage of 29 and under*
Aeronautical engineering..	5,348	2,732	50%
Chemical engineering.....	14,115	9,049	64%
Radio engineering........	5,589	1,748	32%
Physics..................	10,004	3,464	35%
Chemistry...............	65,410	28,332	42%
Mathematics.............	7,967	1,977	25%
Mechanical engineering...	24,651	7,008	28%
Electrical engineering.....	20,818	4,595	22%

Clearly, the accent is on youth, youth that is trained, that has what it takes.

The greatest show on earth is not Barnum and Bailey's circus but the wonderland of scientific research and discovery. Would you like to see it from the inside? Would you like a ringside seat? Then, step up, folks! But first:

Have you the price of admission?

Chapter III

CHEMISTRY AS A CAREER

THE chemical industry in the United States has in the last twenty-five years developed from a small industry to one of colossal proportions — a leader in industry. It is a leader, too, in the number of research scientists it employs. Normally the chemical industry accounts for 21½ per cent of all scientific research employment in the United States! Some 395 of the 1,722 companies that employ research scientists are chemical. Out of every 10,000 wage earners in the chemical and allied products industries, 303 are research men and women.

Some $13,000,000 is spent yearly for research in synthetic and organic chemicals. Recognition of the commercial importance of research is shown by the fact that in 1939, 3.5 percent of the total amount of dollar-sales of synthetic and organic chemicals was budgeted for research.

The practical uses of chemistry are so numerous that it is no wonder that more chemists are employed in industry than any other kind of scientist. From food growing to the manufacture of explosives, dyes, lacquers, cellophane, rayon, medicines, perfumes, textiles, metal products — chemists are in demand. In the manufacture of telephone instruments by Western Electric Company, almost 18,000 raw material items are used. These must be analyzed and tested by chemists.

Chemistry covers so many fields that if you are interested in chemical research, it is wise to decide beforehand the kind of research institute you wished to enter. One institute specializes in medical chemical research; another in the use of farm products for industrial purposes; a third in biology; a fourth in industrial chemistry, etc. About 15 per cent of

all chemists are in the teaching profession. You will find this field, also, a growing one, for chemistry is fundamental in the study of a host of different professions, like medicine, dentistry, pharmacy, and engineering. If you teach at a university you will have a chance to do laboratory research.

You may be attracted by government service instead. You may find your job opportunity with the Department of Agriculture, which probably employs the greatest number of chemists and chemical engineers. If you work in the Bureau of Chemistry and Soils, you may specialize in food research, the chemistry of fruits and vegetables, bacteriological investigations, or insecticides. The Bureau of Animal Industry and the Bureau of Dairy Industry may engage you for various tuberculosis or bacteriological investigations. The Bureau of Biological Survey may need you for the study of poisons and fumigants in its war against pests and rodents. In any case, you will probably begin as a junior aide with a salary of approximately $1200. When you advance as far as the position of senior chemist your salary will be more than tripled.

Your greatest opportunities, however, will be in the field of industrial chemistry. This is really a blanket term covering scores of different but interrelated jobs. Are you interested in textiles? You may become a textile chemist. Are you fascinated by "black gold" and oil wells? You could specialize in petroleum chemistry. There is cellulose chemistry, colloidal chemistry, resin chemistry, electro-chemistry, photochemistry, microchemistry, analytical chemistry, physical chemistry, biochemistry, metallurgical chemistry, dye chemistry, plastics, paper, and pulp, synthetic, organic chemistry, to mention only some of the many breakdowns.

The modern chemist, strangely enough, makes the same claims as did the medieval alchemist – to turn one substance into another. One difference is that he actually does it! He uses formulae, as the alchemist did, but they are not magic

incantations. At the same time, the transformations are as wonderful as anything performed by a sleight-of-hand magician. For example, what if you were one of the chemists confronted with the problem of supplying a substitute for rubber or silk? You would be not at all disturbed. You would make use of easily obtainable oil, coal, milk and wood. By rearranging the patterns of their atoms and molecules into new forms, you would create synthetic rubber and synthetic silk. Nylon, for example: it is even tougher and more elastic than silk.

As a chemist of the near future you may be seeking substitutes for the processes of nature as well as the products. Photosynthesis, for example, a tough word meaning the process by which plants use sunlight as energy to manufacture starch and sugar. Chemists are experimenting with a synthetic process. If they are successful, you will be able to grow plants and vegetables in your cellar with the aid of special lamps.

A hasty Cook's tour through a few of the careers that industrial chemistry has made available, will show you the amazing versatility of chemistry as a profession. Are you attracted by agriculture in addition to chemistry, for example? Then why not agricultural chemistry for you? This is the science that has invented the magic of "chemurgy," the conversion of agricultural products into other substances useful for industry.

Chemurgy is a new term which first appeared in print in 1934. It is a sedate word, but it has within it the roar of a revolution! It has been predicted that one hundred years after the industrial revolution that changed this country from a farming to an industrial nation, chemurgy will work an equally important transformation. Farming will then be pursued mainly for its industrial uses, opening up a tremendous career for chemists.

The man who was more responsible than any other scientist for developments in this field was Dr. George Washington Carver, "the first and greatest chemurgist." The discoveries of this scientist resulted in new industries as well as the saving of billions of dollars. Before Carver began his famous experiments on the peanut, it was only a tidbit for children, elephants and squirrels. By new methods of chemical treatment, Dr. Carver succeeded in extracting no less than 300 different products from this commonplace legume, including beverages, milk, sauces, coffee, salve, bleach, tan remover, wood filler, washing powder, metal polish, paper, ink, plastics, shaving cream, rubbing oil, linoleum, shampoo, axle grease, synthetic rubber. The milk obtained gives a high percentage of cheese, too; 100 pounds of peanut milk yield 35 pounds of cheese, compared to only 10 pounds from the same amount of cow's milk!

This is only a small sample of the miracles achieved by this slave-born wizard. He transformed ordinary sawdust into shining slabs of synthetic marble, strong and weatherproof. He made wall boards from peanut shells, pine cones, banana stems, cotton, etc. From peanut skin he extracted paper fine as linen; from the bare skeletons of cotton stalks left in the fields, he made rope and fibre rugs. He developed 118 products from the sweet potato.

Trained in this branch of chemistry, you too would learn the magic of transformation. Skimmed milk, for example, had only one use, until recently, and that was as food for cattle. You may improve upon its conversion into synthetic wool, paint, waterproof glue. Or again, like Dr. Carver, you may treat soybeans chemically and from this commonplace plant extract not only paints, enamel, varnish, printing ink, linoleum, and plastics, but realize dreams of your own.

One large chemical company used about 275,000,000 pounds of farm and forest products in one year. Into its

factory yards came carloads of corn products, vegetable oils, wood pulp, pine resin, and cotton. Out of its chemical chambers came literally hundreds of different industrial products. According to T. L. Swenson, director of the Western Regional Research Laboratory, fruit waste, in the form of culls or cannery trimmings, needs an economical method to turn it into foods and feed-supplements for humans and animals; perhaps, a challenge for you.

Chemurgy is only one branch of agricultural chemistry. Your special interest and talent may be in the direction of soil or plant chemistry. Good soil contains manganese, calcium, phosphorus, iodine and potash, in addition to nitrogen, iron, and other elements. It may be your job to test for these elements by qualitative and quantitative analysis. If any are lacking, it will be up to you to prescribe chemicals to take their place, much as a physician prescribes a change in diet; only in your case, the patient is Mother Earth.

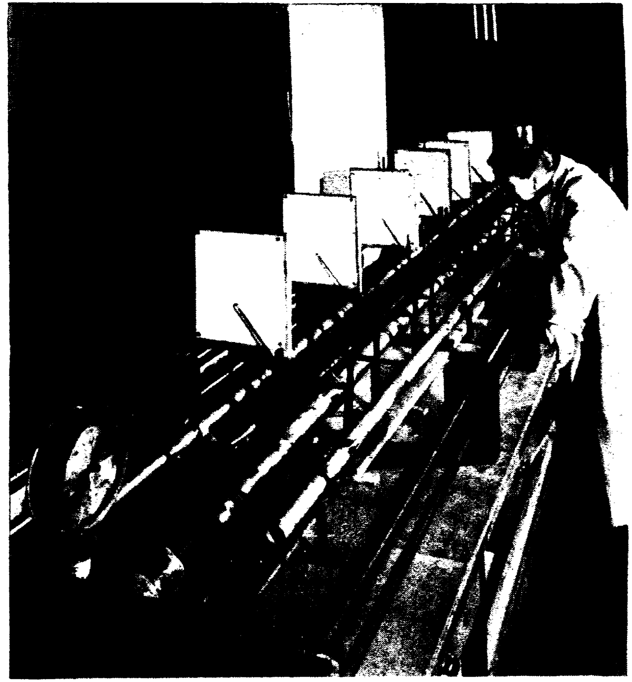
You may study and analyze samples of soils in the laboratory and seek ways to improve the fertility of soil so that better plants can grow in greater abundance. One way to improve the fertility is by making artificial nitrogen fertilizers. The scientific farmer of today does not leave this to the accidents of nature.

Extracting nitrogen from the air was a scientist's dream twenty-five years ago. Today this dream is a reality. You need not worry that the supply will run out: there are 34,500 tons of nitrogen over every acre of the earth's surface, just pleading to be used. Your job may be to remove it from the air, mix it with chemicals and make fertilizer for the soil.

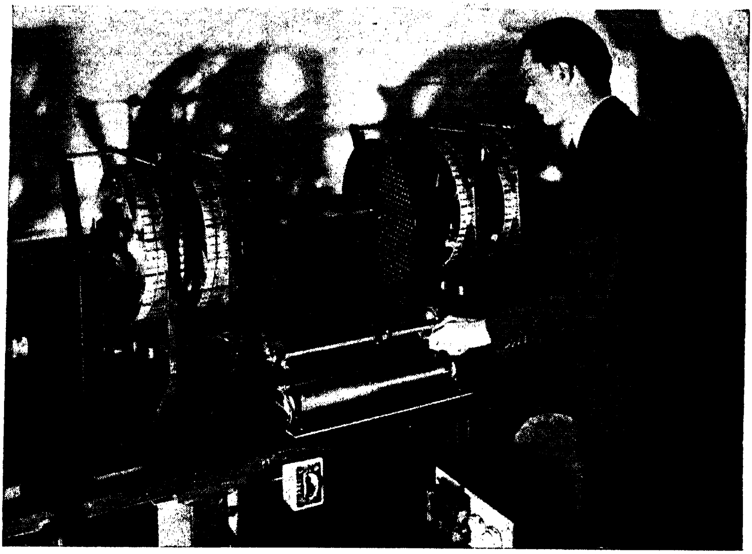
Sometimes the soil contains undesirable elements; selenium, for example, which is poisonous both to plants and animals. Each year, thousands of cattle and sheep in certain western states die from eating plants that have absorbed selenium from the soil. "In years past," wrote Dr. Henry G. Kr[illegible] dis-



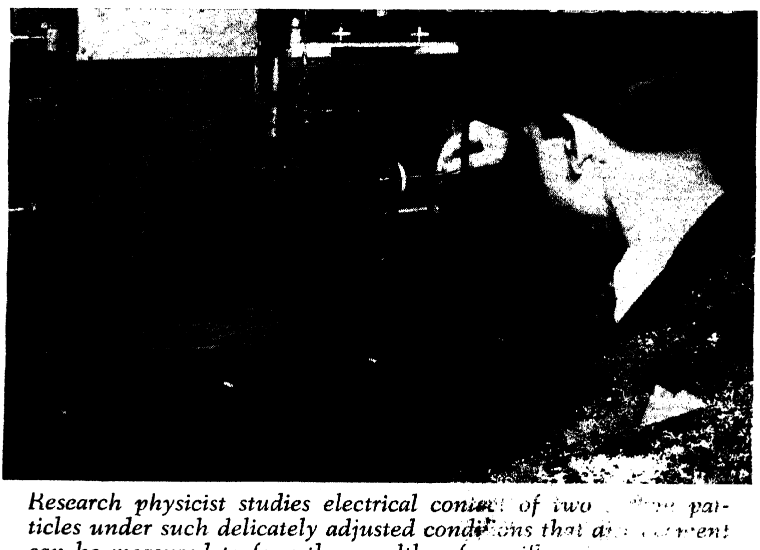
Telephone system engineer works on experimental installation of oscillators for a multi-channel "carrier" system.
(BELL TELEPHONE LABORATORIES)



Engineer studies effect of compression on telephone cable sheath under carefully controlled conditions in the laboratory.
(BELL TELEPHONE LABORATORIES)



New types of "drop-wire," the line which extends from telephone pole to subscriber's home, are given laboratory tests to compare their resistance against wear. (BELL TELEPHONE LABORATORIES)



Research physicist studies electrical con[illegible] of two [illegible] particles under such delicately adjusted conditions that a[illegible] can be measured to four thousandth[illegible] (BELL TELEPHONE [illegible])



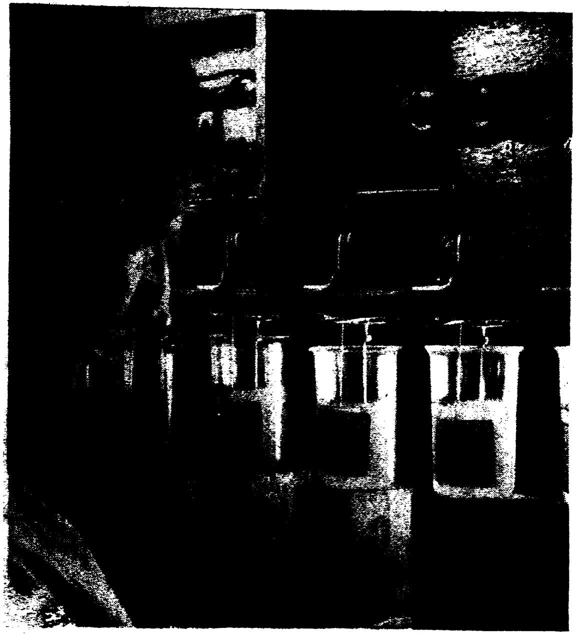
Anna K. Marshall's work in Bell Telephone Laboratories is to study in minute detail, under the microscope, any materials used in the telephone plant, particularly metals.

(BELL TELEPHONE LABORATORIES)



Refrigeration engineering student takes reading in physical testing laboratory of Servel, Inc., makers of gas refrigerators.

(SERVEL, INC.)



...ist "determines" finished copper in laboratory ...issau Smelting and Refining Company, unit ...ern Electric Company for reclamation of non-ferrous metals.

(...TERN ELECTRIC — PHOTO BY WILLIAM M. RITTASE)



Eugenia V. Wyckoff performs computation analysis for important projects at Bell Telephone Laboratories.

(BELL TELEPHONE LABORATORIES PHOTO BY HOLMES I. METTEE)

tinguished chemist, "I have followed the course of a herd of sheep for more than twenty miles across the plains of Wyoming by the dead animals poisoned by eating woody stem which I now know contains enormous quantities of selenium."

Yours might be the task of developing chemicals in the laboratory to kill weeds, as well as insects and pests that injure and destroy crops – like the recently announced du Pont chemical that destroys poison ivy, poison oak, poison sumac and ragweed. Or you might experiment with chemicals for more efficient destruction of rats, bacteria and fungi.

Have you ever seen apple trees "whitewashed" with arsenate of lead to protect them from insects? Recently, the government put research chemists to work to invent a better insecticide. Suppose this had been your problem. You would have to discover a chemical that kills the insects but does not harm the tree itself or the people who eat the apples, and yet does not cost much to manufacture and use. Impossible? The chemists found the answer. And not only that: they discovered that the same new product (Phenothiazine) is an effective cure for urinary diseases, both in man and in animals!

Again you might choose paper and pulp chemistry, and specialize in the study of trees and their products. Paper, for example, of which there are today 7,000 different kinds. But paper is not all. You would go further and study better ways of converting paper and wood pulp into rugs, combs, dolls, baskets, hats and pails. It is from the cellulose of plants that the new synthetic materials emanate. You may be busy with test tubes, retorts and formulae for the conversion of sawdust (until yesterday, fit only for the floors of butcher shops) into plastics, alcohol, sugar, glucose, fuel for automobiles.

So recent are developments in this field and so new the [illegible] that it was not until 1943 that the first large-scale

plant in North America was established for the conversion of wood into sugar for alcohol. What a thrill you would have gotten if you had been a wood chemist at Brooklyn Polytechnic Institute at that time. For it was this institution in Brooklyn, New York, that was responsible for the achievement which the wood industry hailed as the beginning of a new era for lumber. Chemists at the institute made discoveries in their laboratories that reduced manufacturing time from many hours to eight minutes. The process, developed by Professor Donald Othmer and his associates, makes it possible for the first time to convert sawdust into raw sugar by a continuous process of manufacture.

There are still many unanswered problems in this field. Perhaps you will help to solve them. One puzzle is lignin, the glue that seems to hold the fibres in wood together. What is its exact molecular structure? Nobody knows. When the answer is found, many new uses for this glue-like material will be available.

As a wood chemist you may tackle problems similar to the one first investigated by chemists working in the Forest Products Laboratory of the U. S. Department of Agriculture. They set out to convert ordinary soft wood that swells, shrinks and warps easily, into hard wood that is stronger and more durable. They developed a successful process which was later brought to a final development by Dr. J. F. T. Berliner of du Pont. It is interesting to see just what these chemists accomplished.

The chemical agent used in the new process is called methylolurea. It is impregnated into the soft wood in a water solution. It reacts with the wood to form hard, water-insoluble, unmeltable resins. The treatment can be used to harden the outside without affecting the interior of the wood, as in case-hardening steel. When the process is used generally, dresser drawers no longer will stick in hot weather, as sticking

is caused by swelling of the wood, due to humidity. The discovery means also that wood need no longer be regarded as inflammable; chemically treated, it does not support combustion.

Food chemistry is another fascinating field. Any number of opportunities are present. You might concentrate on the study of nutrition, conducting research on animals, their enzymes and digestive processes. You might make artificial vitamins for building health. (Pellagra, for example, is a common disease in certain parts of the South because of lack of vitamins in the pork and corn diet that makes up the meals of many share-croppers).

You may become a consultant to the canning industry for problems of food preservation. A new development in this field is "dehydration," which means the removal of about 90 per cent of water from food to reduce its bulk for storage and transportation. So tiny does each article of food become by this process that a housewife can provide enough food for fifty-two guests with only one pound of dehydrated food.

You may specialize in glass chemistry. In this field you may analyze the chemical composition of windowpanes, spectacle lenses, glassware. On the other hand, new glass products have been developed in recent years that do not even look or act like glass. Fibre glass, for example. It can be bent like rubber, twisted like thread, woven like linen, and it jumps back like a sponge after pressure is applied.

How is it made? The answer to this question is one of real scientific achievement. The original glass may first be molded into marbles, each weighing about a quarter of an ounce. In the base of the furnace chamber are many fine holes. The 200 or more filaments of glass that flow through these holes are gathered into a strand by a high speed winder. The glass fibre can actually be spun and woven on standard textile machinery. And yet their tensile strength is greater than that of

steel. The scientists behind this accomplishment must have a great feeling of inner satisfaction. Consider some of the many uses their process has resulted in.

Fibre glass is used as: electrical insulation, filtering medium in air filters, decorative fabrics for bedspreads and curtains, sound-proofing for airplanes, oil stove wicks, etc. You may study and improve this strange product, or its amazing cousin, black nontransparent "Foamglass." This "glass" can be sawed like wood and floats like a cork. It has 5,000,000 air cells to the cubic foot and is moisture-proof, yet rigid and amazingly light. It is used as insulation against heat for refrigerating rooms and also to replace cork as a filling for life preservers and life-rafts.

On the other hand, you might be a petroleum chemist, and aid in the search for oil and its extraction from the wells. Your main work, however, would be in the refining laboratory. Here the crude oil is broken down into gasoline, kerosene, lubricants, etc., by "fractional distillation."

The oil industry today manufactures not only motor fuel and lubricating oils but paint, varnish, resins, insect sprays, soaps, candles, medicines. Research chemists claim this is only a beginning. As petroleum chemist you will conduct experiments to develop explosives, paper textiles – yes, even food itself from crude oil.

The Lilliputian world of chemistry is one known as microchemistry. It is an intriguing world offering you the opportunity to become a laboratory detective working on infinitesimal clues. For example, an engineer might give you a bit of cloth smeared with a film from a commutator in a steel mill. That is the only evidence available. What is the nature of the film and what causes it? A vexing industrial problem that has baffled engineers waits for your solution.

As a microchemist, you will work in a special "micro" laboratory. Instead of the usual-sized beakers, flasks and seven

inch tubes in racks, you would use miniature retorts, one inch test tubes and one inch porcelain containers for crucibles. And instead of heating the "crucibles" in an electric furnace, you will slip them into the tiny tubes which are inserted in heating units.

Most remarkable of all your tools, however, will be the "micro-balance," a chemical weighing machine so delicate that it has to be kept in an air-conditioned chamber which is cleaned of all dust particles that might disturb it by an electrostatic air cleaner. With this airy machine, delicate as a breath, you will be able to measure one millionth of a gram or substances 100,000 times lighter than a pin. When depositing the microscopic material to be weighed on the balance pan through the doors of the glassed-in cabinet containing the scales, you will have to be careful to insert both hands at the same time, otherwise the heat from one hand would be sufficient to throw the instrument off balance!

Other instruments you would use are the spectroscope, which enables you to analyze a substance by the "spectrum bands" revealed through the instrument when it burns, and the electronics diffraction camera. By this camera, you will be able to tell whether a coating that has developed on metal is harmful corrosion or beneficial protection. Billions of electrons bouncing off the coating in a three foot long vacuum tube, strike a photographic film, tracing a picture and, by studying the pattern of semicircles on the developed film, you will be able to analyze the coating.

In the field of metallurgy, which belongs in the no-man's land between chemistry and physics, war demands have resulted in new discoveries and technics. That spells improved metals and more demands for metallurgists in the postwar era. The electric flameless forge, for example: in a few seconds, it heat-treats steel to red hot temperatures and hardens machine parts, as well as making steel malleable. There are no

flames in this streamlined village smithy's forge. You can put your hand right in the center of the coil, while 500 kilowatts of electricity pass through it, without even feeling warm. Yet a piece of steel inserted in the coil becomes red hot speedily, due to "inductive heating." As a metallurgist you will be able to harden steel surfaces to any depth and width with this high-frequency generator, giving a shaft a hard surface at points where it must resist wear without making the shaft as a whole brittle, which is the effect of ordinary heat-hardening methods. Your work in the laboratory might involve testing metals, preparing alloys, processing materials and submitting them to heat-treatment. You may study the properties of new alloys and processes and help to solve problems of welding. You might be employed in the department of magnetics to apply and develop magnetic force to production methods and create permanent magnets.

You might develop a new magnetic silicon steel like hipersil, which was the result of a $2,000,000 search for more powerful magnetic fields necessary for the operation of electrical machinery. This discovery stepped up the magnetic flow in steel by one third and is equivalent in importance to making copper wire carry a third more electricity without stepping up the voltage. Used in transformers, hipersil will save 5,000 tons of copper and high grade alloy each year.

Metallurgists are searching continually for stronger metals that will withstand higher temperatures. You might mix hundreds of batches of different alloys, looking for "temper-hardening," testing and sampling again and again. In this way the new metal alloy, K-42-B, was discovered after a six year search; containing only 7 per cent of iron, it is stronger than any known kind of steel, and will stand up under temperatures 200 degrees hotter than the melting point of copper. This means better, more durable dies, valves, steam fittings.

Metallurgists are developing new uses for molybdenum,

now pinch-hitting for nickel and tungsten because of war shortages. Aluminum output has doubled, due to its use in airplane construction. You may experiment for new alloys of this metal, combining its natural lightness with necessary strength.

Wartime chemical development has set in motion new forms of expansion of industry. Chemical engineers have improved manufacturing processes so chemicals can be produced at lower cost and in greater volume. Transportation also looks to the chemist for protection and improvements. Which explains a recent showerbath that lasted five weeks! No, it was not a human being who underwent this too cleansing experience but a new insulating varnish that was being tested, for better protection to the coils of street car motors exposed to rain. While the varnish coated coils were thus drenched, day by day, a special testing instrument tuned in on the motors to check their efficiency. The varnish came out of the test with flying colors.

New materials have also been created in the chemical laboratory, like resins, triptane fuel, and the famous germ-killing penicillin, discovered in England but developed in this country. These new developments mean continued expansion of chemistry and new jobs and careers for the college trained man or woman today.

Proof of government recognition of the importance of research chemists is given by the authorization in 1938 by Congress of an annual appropriation of $4,000,000 for the establishing of four regional research laboratories under the auspices of the Department of Agriculture. The sole object is to search for new and wider industrial uses of farm products.

The northern laboratory in Peoria, Illinois, specializes in the conversion of corn, wheat and agricultural waste. The southern laboratory, in New Orleans, is working on cotton, sweet potatoes and peanuts; the eastern laboratory, in Phila-

delphia, specializes in apples, tobacco, milk products, etc.; and the western laboratory in Albany, California, is investigating wheat, potatoes, apples, etc. There is an average of more than forty scientists at each laboratory with about twenty-five sub-professional employees. Altogether, there are more than four hundred persons already at work in the laboratories and expansion is being planned.

These laboratories are typical of the advance of chemistry in all fields of industry. The situation was illustrated by an amusing incident, recorded editorially in the *Saturday Evening Post.* In a fiction story by Isabella Holt, one character explained that he obtained a job for a chemist by simply phoning "Phipps at Arco," and added: "He's so frantic for chemists that he hired her, sight unseen." It so happens that there is a real T. J. Phipps, who is vice-president of Arco Company of California, Ltd., manufacturers of paints. He wrote to the magazine, saying: "You can tell Isabella Holt for me that I am still frantic for chemists. Perhaps she can send me nonfiction chemists!"

This great demand for chemists and chemical engineers is not a temporary war phenomenon. The resumption of production of civilian goods will require more of them than ever before, to turn to industrial use the many chemical discoveries and improvements that have been furthered during the war. One thing is sure: the graph line of chemistry as a career points sharply upward in the postwar period.

Chapter IV

MORE CAREERS FOR THE CHEMIST

The time has come, the chemist said,
To talk of many things;
Of poker chips, umbrella tips
And combs and teething rings;
Of minnow traps and bottle caps
And toys and button hooks;
Of banjo picks and magic tricks
And clasps on pocketbooks;
Of blotter tops, electric clocks –
The number is fantastic;
And all these things the chemist brings
Into the world with plastic.

Anonymous

MODERN plastics are combinations of organic compounds that can be molded in any shape to form new materials not found in nature. Celluloid, for example. You may laugh at the celluloid collar of the gas-lit period; yet this substance was the first plastic that was ever invented. Back in 1868, a printer by the name of John Wesley Hyatt, entered a contest for the invention of a substance that was cheaper than ivory for billiard balls. He combined paper pulp, nitric acid, cotton linters and camphor. The result was celluloid, which soon found thousands of uses more important than billiards. In 1890 came the second plastic; it was non-inflammable and served admirably for buttons and buckles. Its inventor was Dr. Adolph Spitteler, who had dreamt, not of buttons but of white blackboards! He created it by mixing formaldehyde and cow's milk. Finally in 1903 came bakelite, better yet because it maintains its shape when hot and does not warp.

This new plastic soon became a household word and found a thousand purposes in industry.

The increasing use of plastics in all fields of industry is so widespread and recent that this is sometimes called the Plastic Age. As a chemist, engaged in this field, experimenting with plastics may be your special province. You may check the soaking of strips of paper or cloth in liquid bakelite and the cutting of these strips into sheets which are piled one on top of the other for thickness and cured in a hot press. This material can be sawed and drilled like a wooden board; or else, chopped into bits and forced into a mold, it can be changed into any shape desired.

Laminated plastic cams are actually taking the place of cast iron cams in shoe-sewing machines! Because of their lightness, they are doubling production at half the cost. It took the chemist to prove the unbelievable fact that featherweight paper or cloth can be made more durable than iron; laminated plastic does not chip or rust and is therefore superior to metal in streetlight reflectors. It is also a good electrical insulator; weighs only half as much as aluminum; does not warp or crack and, believe it or not, has the tensile strength of structural steel!

There are scores of plastic chemists and room for many more. Plastics are being used everywhere for rubber substitutes, textiles, furniture and in the building industry. They have the strength of metal, the lightness of wood and almost the transparency of glass. Every time you comb your hair, brush your teeth, write with a fountain pen, you are probably using a plastic of one kind or another. Your automobile may have as many as 200 different plastic parts; plastic is also part of your radio, dishes, chess pieces, typewriter keys and camera lenses. Plastic lenses may soon revolutionize the optical industry; they can be thrown out "like cough drops" from the molding machines and cost only a few cents to

produce. It is impossible to describe the various needs met by this material in the electric power transmission, radio, telephone, automobile and airplane industries. Nor is the end in sight! Agricultural products are being utilized for new plastic sources. Sugar beet pulp, for example; also lemon and orange peel. When you throw an orange peel away, you are discarding at the same time plastic strings for musical instruments or plastic plywood of superior quality. A new kind of plastic is born in the chemist's laboratory almost every year.

"It just grows all by itself," Dr. J. J. Pyle, director of the General Electric plastic laboratory, says of a new type of plastic foam. Even the GE chemists who had a hand in this development must be amazed at the sight of this plastic foaming into 30 times its own size. A quart can of the mixture will expand sufficiently to fill a 7- to 8-gallon receptacle in about 10 minutes. What little heat is needed is self-generated by the mixture itself. The new plastic foam is particularly good for insulation.

Your job in plastic chemistry might be to discover and develop new or improved plastics. Recently Westinghouse chemists engaged in this kind of activity produced micarta. It is used for bearings in propeller shafts to replace rubber and bronze. It replaces wood bearings in ships, and is better than wood since the latter cracks under the pounding of stormy seas. Micarta is also better than metal for this purpose, because salt water corrodes metal bearings but has no effect on the plastic. Made of cloth and resin, it is another plastic that has the strength of steel.

Typical of the most recent arrivals in the field is Cerex, the first thermoplastic ever developed that can hold its shape and strength in boiling water and yet be molded in double quick time. Scientists report that this plastic will open up an entirely new field of industrial and household applications

because of its heat-resistant qualities which make it superior to the usual cellulose acetate.

> Regarded from the technical standpoint, synthetic rubber is today no longer a practical proposition.

This statement was made by an eminent German scientist as recently as 1925. Since then, so rapid have been the developments, that some 30 commercial types of synthetic rubber have come into industrial use. Today, rubber chemistry is a new field beckoning with new jobs and careers.

What is rubber? It is a fluid called latex that came chiefly from the bark of the Hevea tree before the war. In recent years, Uncle Sam has been harvesting rubber from imported plants, mainly Russian dandelion and guayule, native to Mexico. In addition, goldenrod, milkweed, and rabbit brush are being investigated as promising sources.

In 1839 a Philadelphia hardware merchant, Charles Goodyear, spilled a mixture of crude rubber and sulphur by accident on a hot stove. That is how vulcanization was discovered, bringing new opportunities to chemists. The new vulcanizing process and its later developments spurred on the demand for chemists still more, because of the increasingly wide assortment of rubber, differing in properties, that resulted. For example, inner tube rubber is airtight; rubber for mattresses and pillows has millions of air spaces; rubber for balloons can expand rapidly; rubber for containers has a special hardness. One kind of rubber "rubs out" noise; another supports heavy loads.

You have heard of synthetic rubber, which came to the rescue when natural rubber supplies were cut off with the attack on Pearl Harbor in 1941. Chemists in the rubber industry were then faced with an immediate and crucial test; could they furnish enough synthetic rubber to satisfy the

thousands of war and industry needs? Research chemists rolled up their sleeves. At first they sought a solution by attempting to duplicate the processes of nature in building the complex molecules of rubber from simple, hydrocarbon molecules called "isoprene." Failing this, they started out in another direction, using as their source petroleum, alcohol, acetylene or coal. This time they succeeded. The new type of rubber while not as elastic and as satisfactory for heavy truck tires, is superior to natural rubber in resistance to sunlight, heat, and age. Probably the best known is the famous "Buna S." Although there are differences of opinion as to relative merits, the battle of synthetic rubber has been won. Improvements in this material, serving a thousand uses in industry for tires, tubes, belts, insulators – are being reported every few months. It may be your opportunity to have a share in still further improvements.

If you are looking for a new and expanding field of chemical research, synthetic rubber is one answer. A survey in 1943 showed that only 5 per cent of the applicants for this work were over thirty-five years of age. One large corporation reported that 80 per cent of its technicians, production superintendents, foremen, managers and chemists had less than five years of actual, industrial experience. Only within the last year or so has synthetic rubber chemistry been included in university courses. In 1943, the Illinois Institute of Technology at Chicago graduated its first class, after sixteen weeks of study under government sponsorship.

Before the war, synthetic rubber cost more to produce per pound than natural rubber, but wartime improvements in manufacture have cut down the difference. In 1944, Harvey S. Firestone, Jr., president of the Firestone Tire and Rubber Company, stated that synthetic rubber would be produced for about fifteen cents a pound, compared with the pre-war price of twenty cents for the natural product. The chief

shortcoming of the synthetic variety is its inability to withstand high temperatures. This problem is being mastered, however, and the demand for experts and technicians is growing. In 1943 the War Manpower Commission announced 20,000 trained workers would be needed when the new industry gets into full swing. Here is a field that is not overcrowded.

You might become a textile chemist. You have, of course, heard of nylon and rayon, the new synthetic fabrics, and how they have revolutionized the cotton and silk textile industry. Here the textile chemist reigns. What he has accomplished so far is only the beginning of new developments in the field. Have you heard of the durable cotton canvas houses? As the chemist turns paper into a steel-like material, so he converts cotton into brick walls. The cotton dwelling has passed the experimental stage and has been found to be entirely practicable for living purposes. If the leap from clothing to houses seems an incredible one, consider these words written by an authority: "It is difficult to say just where the work of a textile chemist begins and where it ends."

As a textile chemist, you would be faced by a wide choice of specialties: cotton chemistry, nylon chemistry, wool chemistry, etc. Each product involves its own problems and operations that require highly specialized training to master. In all these fields, however, certain operations are fundamental: removing impurities before spinning begins; bleaching and dyeing and even the development of special lubricants for the power looms, owing to the delicacy of the fabrics.

Most important is the coal-tar dyeing process. You might devote your entire career to this fascinating field. In 1856 an eighteen year old boy named William Perkins made chemical discoveries that laid the foundation for this process. Since then, the thousands of gay or subtle and sudbued tints and

hues used in textiles have become so familiar that you accept them as a matter of course.

Stranger still, the drab chunk of coal is the source from which all this tinted beauty springs. It is coal tar, residue of heated coal, that gives forth aniline, naphthalene and anthracine, from which dye stuffs are made. But the process took many years to develop. A generation ago, the United States depended on Germany for its supply of dye chemicals. During the First World War when these supplies were cut off, the army and navy did not have enough fast-dyed uniforms for their soldiers and sailors. Workers in dye factories scraped the floors to salvage precious ounces. Today, the United States is making 95 per cent of its own dyes. The wartime headline so alarming to the fair sex: "Women Mob Stores in Rush to Buy Last Colored Dress," was a growing possibility during the last war, but is now impossible, thanks to the chemist.

As a rayon chemist, you might treat wood pulp or cotton with chemicals and convert them into the new synthetic which has done so much to free the American people from humiliating dependence on the silk worm. Rayon wears better than silk. Celanese does not shrink. But chemists are never satisfied. They are experimenting for still better substitutes. You, too, may be engaged in the constant search for new synthetic materials. Here are problems to be solved, also. Some synthetic materials lack the softness and flexibility of silk; they wrinkle when crushed. It might be your job to overcome these limitations and develop better materials.

In the nylon chemistry laboratory, you may create nylon from the raw materials of coal, air and water. Besides being a substitute for silk in ladies' stockings, it has many other uses: laces, fly screening, surgical sutures (for sewing wounds), toothbrush bristles, violin strings, insulation for electric wires, etc., as well as parachutes. Cotton and silk

may thus go the way of bustles and the Model T Ford, thanks to the textile chemist. In addition, you may make other textiles from bark, wood pulp, cotton linters, and coal. Textile chemists have even proven that the old saw, "You cannot make a silk purse out of a sow's ear," is not true – if the sow's ear is chemically treated.

In 1943, America's mills produced fifteen billion yards of cloth and nearly 88 per cent of it went to war. What a far cry this is from the American Revolutionary War when soldiers had to depend on charity for donations of blankets and hand-woven clothing! There was little work for the chemist then. The giant textile mills of today with their thundering power looms have not only created new jobs for thousands of chemists and chemical engineers, but these chemists have also created new careers and opportunities by research and application of new, synthetic materials, unknown before.

If you are interested in diseases of the human body as well as chemistry, you might become a biochemist. You may make chemical compounds, like the famous sulfanilamide drugs, or extract penicillin from a mold to combat diseases.

Recently, quinine was put together in the laboratory for the first time in history. Quinine is an important remedy for malaria and is found in the bark of the cinchona tree.

The synthesis was accomplished by two twenty-seven year old American chemists, Dr. Robert B. Woodward of Harvard and Dr. William E. Doering of Columbia University. It took them less than fourteen months of research to achieve their triumph, although chemists had been trying to make synthetic quinine for a hundred years without success! The young chemists used a coal tar derivative which they subjected to a score of chemical processes before finally obtaining the precious drug.

If history does not repeat itself, it seems to try, pretty

persistently at times. For less than a century ago, William Perkins, decided to spend his Easter vacation in his attic laboratory in London and attempt to make quinine in a test tube. He failed, but discovered, as you know, the first coal-tar dye instead. Young Woodward and Doering also spent their Easter vacation in a laboratory, and for the same purpose. They succeeded brilliantly, and no discovery could be more timely, for the Japanese had taken over the cinchona groves of Java, which produced nearly all the quinine in the world. Malaria was spreading on account of war migrations. Even before the war, 3,000,000 people died of malaria every year.

Slender, bespectacled Robert B. Woodward won his Ph.D. at the Massachusetts Institute of Technology at the age of twenty. He and William Doering, who was then at Harvard, set to work on February 1, 1943, studying the complicated quinine molecule represented by a two-foot wooden model of fifty-two balls, variously colored to stand for carbon, hydrogen, nitrogen and oxygen atoms.

They worked for months to create a chemical skeleton of the molecule to which the necessary atoms could be added. When Doering took a teaching position at Columbia, they collaborated by mail. The two came together on their Easter vacation and worked feverishly against time. Late one night on the last day of their vacation, they finally struck oil: fine, yellow, interlaced needles of quinotoxine, from which quinine is extracted, took shape before their eyes!

The cost of the quinine as produced by these two young scientists is prohibitive and runs into thousands of dollars for a dose. The next job, and here is where the chemical engineer comes in, is to develop large scale production by inexpensive methods. Will it be your contribution to perfect such methods?

Again, chemists had been hunting twenty years for a

preparation that would heal bone injuries. In 1942, they seem to have found it. In a dramatic demonstration, scientists drilled holes in the thigh bones of living rats. Then the new chemical (vitamin C and calcium) was injected. Result: the holes healed rapidly.

You may experiment with chemical solutions to prevent tooth decay, like the newly discovered treatment with sodium fluoride. You might develop a chemical that destroys malaria-bearing mosquitoes, like the mysterious "Formula 612," known for the duration of the war only to army and navy officials. You might make synthetic vitamins, so important to human health. It was the research work of industrial chemists on vitamin D in poultry, recently, that pointed to greater abundance of poultry, meat and eggs.

You might apply chemistry to another field of biology,—insect-control, for example. Recently, as reported by the American Chemical Society, chemists devised a way of killing insect pests by making them thirst to death! It was discovered that powders made of coal ash clinkers or very fine diamond dust, covering the outer casing or skin of weevils, beetles and moths, keep out the necessary moisture, causing them to die of thirst.

Whether you work in biochemistry, plastics or chemurgy, to be a successful chemist, you must have an analytical type of mind. You must be observant of the slightest details and like a super-detective, be able to follow microscopic clues that point to answers of unsolved problems. At the same time, the research chemist is also the idea man in the industry: he must be able to run ahead of the facts and create theories that will be supported by laboratory findings.

Salaries in chemistry vary considerably. As in other scientific fields, earnings are low at the beginning but increase with length of service and increased responsibility. The schedule of salaries mentioned applies to normal peacetime conditions.

If you wish to break in as a chemical worker before you get your degree, your salary would be around $25 a week. As a college graduate, you would receive from $30 to $40 a week. Your first job may be as a technician. You might draw samples of milk from a vat, for example, and test it with lactic acid to determine if curds will form and if the milk is ripe for conversion into cheese. These operations could be learned in a short time.

Laboratory assistant is the next step at around $40 a week. These jobs will give you excellent preparatory training in chemical technique. If you develop into a control chemist, you may test the qualities of raw materials and then the product of each manufacturing operation and finally the finished product itself. In the food industry, you may test for bacteria as well as chemical composition. By thus controlling the manufacturing process from beginning to end, you would be maintaining uniformity of quality. Your salary would be $1800 to $2400 a year. As relief chemist, you would earn $2000 to $3000 a year.

On the other hand, you might be a research chemist and seek new methods of manufacture as well as new products. You would work in close association with the chief chemist and executives. Your salary would be between $2500 to $4000 a year. Remember, though, that this salary is relatively high. Only 10 per cent of all industrial chemists are in this group.

As chemical engineer, you would earn $3000 to $5000. You may design machinery and plant equipment. It was chemical engineers, for example, who designed the machinery used in the "cracking" process which increased the yield of gasoline from crude petroleum. You would also be in charge of operations. Note again that this income is tops. Only 5 per cent of all chemical workers are in this group.

Highest paid of all are the executives, for they have the responsibilities of over-all supervision of the plant. They

earn $3500 to $10,000. As an executive, you may supervise the laboratories and chemical tests and act as scientific advisor to the management on production, development, and research.

As a junior chemist with the Civil Service you would earn about $2000. When you reach the grade of "chemist," your pay would rise to the $2600 to $5600 scale. Chemical engineers in civil service receive the same salaries as chemists.

The prime importance of chemistry to industry and commerce is universally acknowledged not only by scientists but by industrialists and financiers. One of the most impressive tributes was paid to the chemical industry by an investment house, Merrill, Lynch, Pierce, Fenner and Beane. To quote from their survey report: "If a true list of essential industries is ever compiled, the chemical industry will inevitably be near the top of the list. For industrial chemistry is not only as essential to peace as it is presently in war – it is vital to life itself. And it is literally true today that industry as a whole cannot function without the chemist. The chemical industry, then, is the base from which all other industries stem to form the complex structure that is our national economy and the American way of life. So industrial chemistry is not just essential; it is indispensable."

Chapter V

PHYSICS: NEW CAREERS IN A NEW WORLD

"READY? GO!"

While you watch, the engineer throws a switch. Leaping across the gap between two generators, a flaming arc, 20 feet across, weaves a blinding pattern of 2,000,000 kilowatts of electricity. How about the safety fuses? Being the old, traditional kind, they explode like shells from the incredible charge and six inch timbers are blasted into kindling wood.

The new type oil circuit breaker, 12 feet tall and enclosed in a brick-walled test chamber, is now called into play. Again the blinding arc flashes. One twentieth of a second after it is released, the circuit breaker grunts. The flood of power is blotted out "quicker than an eye-blink."

This experiment in the laboratories of the Westinghouse East Pittsburgh Works shows that, thanks to the physicist, man can now create a terrifying discharge equal to 75,000 lightning bolts with power enough to drive twenty modern battleships and then snuff it out like a candle flame! What does the new circuit breaker mean? It means improved power system defences against lightning and short circuits.

Meanwhile, on another front, physics is called in to solve a murder mystery. A tiny stain has been found on the shirt of the suspected man. He has denied all connection with the crime. Is the stain one of human blood? The spectroscope, a telescope-like instrument that enables the scientist to analyze the chemical composition of any substance, will give the answer. The spectroscope rarely fails, and a man's life hangs in the balance.

From electrical engineering to biology and medicine, the domain of physics is broad and covers a hundred fronts. In

ancient times, it dealt only with mechanics, optics, and astronomy. Today, in the words of Shakespeare, it "bestrides the narrow world like a colossus." Physics is the science that deals with the physical qualities and behavior of matter, as well as forces, energies, and radiations. Without the discoveries of physicists, we would have no newspapers, sanitation facilities, electric power, telephone, radio, airplanes, subways, factories, machinery, skyscrapers, electric lights.

Physics includes all branches of engineering – civil, mechanical, electrical – except chemical. It embraces acoustics, the science of sound and hearing; thermetics, the science of heat; optics, the science of vision, light and lenses; hydrodynamics, the study of water, its movement and pressure; radioactivity, the study of high frequency radiations.

The science of physics offers a wide choice in a score of different fields. You may be a technician or consultant in transportation and communication industries; a meteorologist with air lines; a climatologist on soil conservation projects; a specialist in glass manufacture; a consultant in oils, textiles, radio. You may design instruments for medical men, like the radio knife for surgical operations, germ-killing X-ray tubes and the electron microscope. You may do research in cosmic rays, radar, atomic energy. To you may be entrusted the problem of developing cheaper sources of power, a major problem of industry, or designing sound proof plane cabins.

The largest corporations have research laboratories in physics, for along with the discoveries in science has come the discovery of business that research pays high dividends. A survey in 1933 showed there were 1,575 laboratories in the United States. This number has grown rapidly since then, especially under the impetus of the war program. The growing need for physicists in all fields is reflected in the increase in registrations by college students. At Barnard College, for example, in 1943, physics led all the sciences in the increase

of registration over the previous year, with a gain of 67 per cent.

Trained in physics, you would be qualified for interesting positions in government service as well as in education. You might be employed by the Bureau of Standards in Washington, one of the greatest laboratories of its kind in the world. Here a small army of physicists, chemists and technicians specializes in analyzing and testing materials.

Teaching offers another opportunity. As university instructor, you would have an opportunity to do research in physics in the university laboratories. You would also be in line for the next higher position of associate professor.

Probably the most fruitful and exciting field in physics just now is electronics. This is the science of the electron, the negatively charged particle that whirls about the center of every atom of matter. It was Thomas Edison who first stumbled upon the electron without knowing it. He noticed a peculiar bluish glow between a filament wire in his electric lamp and another wire connected with a metal plate inside the bulb. Not until thirteen years later, in 1896, did J. J. Thompson, famous physicist, discover that this glow was caused by a discharge of electrons liberated when the filament in the lamp was heated.

The so-called Edison effect was the basis of later discoveries that grew into inventions of the radio, television, electron microscope and many other magical electrical machines. Physicists like Fleming, De Forest, Langmuir and Richardson developed and improved high frequency tubes for radio reception and also electrical equipment to speed up industrial operations.

Developments in this field by physicists include the rectifier, which changes alternating current into direct current; also, the "grid" which enables the flow of electrons to be controlled for the first time. The transmission of short waves

from radio stations would have been impossible without the development of high power tubes, largely the work of Dr. Langmuir. These tubes are responsible for radio broadcasting, which displaced Marconi's wireless telegraphy, hailed as a revolutionary discovery in physics only fifty years ago!

Working in electronics, you might experiment with improved electron tubes. These are veritable Aladdin's lamps, which call forth the genii of lightning itself as a slave to do the master's bidding. Already there are many types, from tiny globes to cylinders several feet high. Employed in radio and television, they have a score of other applications, which in turn open new careers and jobs in research and industry. One type is used in a machine called the spectrophotometer, which accurately and automatically separates papers and textiles in accordance with 2,000,000 shades of color! It has an important use in classifying paints and chemicals, also.

Electronic devices wrap packages automatically at high speed, remove slate from coal, level elevators, open doors automatically as you approach, turn on lights automatically when it gets dark, switch them off when it gets light, control punch presses, detect and register smoke and fumes, record defects in heavy steel castings and automobile tires, separate good oranges from defective ones, and automatically "count" the number of people in a room.

That is not all. They detect the approach of planes through pea-soup fog, aim and fire guns automatically, magnify submicroscopic viruses up to 100,000 times in the electronic microscope, disclose broken bones by means of the X-ray and, by the same means, destroy cancer and gangrene in the body. The tremendous saving in labor power afforded by electronics is shown by a recent estimate: its value has been compared to the acquisition of 100,000,000 new and skilled workers.

What limits the work that the electron slave can perform?

The limitation of speed. Experimenting in the laboratory, you may try, like a racing driver, to break all electron speed records. To do this, you might smash atoms in the "cyclotron," using heavier atoms as hammers. In this way, you would create a new kind of atom that is very unstable in character and explodes. Every time this happens, a free electron leaps out, traveling at the rate of 400,000,000 miles an hour! It has been calculated that a powerful bombardment of uranium atoms by "neutrons" would release 175,000,000 volts of energy.

The new giant 225 ton cyclotron of the Carnegie Institution at Washington generates atom-smashing projectiles of 15,000,000 electron volts energy. Requiring four years to build and costing $500,000, it is housed ten feet beneath the earth's surface to prevent cyclotron radiations from reaching people outside, as mice have been known to die in a few hours from exposure to these radiations. It is operated by Dean B. Cowie, the physicist in charge. This is the new tool that you, too, may use while probing the mysteries of the atom and measuring the forces released by its disintegration. You may sit at the control board, a huge, organ-like console, a considerable distance away from the cyclotron itself. You would be protected by specially constructed insulating walls.

It would be quite thrilling to operate this control board. Imagine before you the seven main switches with more than 100 smaller switches and a maze of dials and meters. Only by pressing the right switches in the right order can you make the cyclotron operate. In a window of the 60 inch accelerating chamber is placed the element that you wish to bombard. Here it receives the full force of the atom-smashing beam of atomic projectiles which are first whirled around the chamber in continually widening circles at tremendous speed.

The cyclotron is a huge affair, 30 feet long and 20 feet high. It is essentially a tool of research, the offspring of a

theorist and not an inventor. Yet who can tell what revolutionary industrial applications it may result in? As Mr. Cowie said, conservatively: "The results of experiments conducted in the fields of chemistry, biology, physics and metallurgy with the cyclotron will be of great value in molding a better postwar world."

Atom smashing brings closer the dream of the twelfth century alchemist, for, by changing one atom into an atom of a different kind, you create a new substance unknown before. The chemist does it with plastics; you would be doing it with electrons. Rutherford changed nitrogen to hydrogen in this way. By rearranging the pattern of electrons and protons (central particle) that make up each atom, you could create up to 400 new substances, although only 92 elements in nature are known to the chemist!

Electronics serves not only industry, but medicine. You might become a biophysicist and apply electronic devices as weapons against disease. When Madame Curie discovered radium, she inspired millions of sufferers from cancer with hope. But radium is rare; two pounds cost $20,000,000. Electrons are cheaper and just as effective. Working with doctors, you might destroy cancer cells by means of electrons shot out of high voltage X-ray tubes. Experiments on animals with these tubes showed that the deeper the cancer cells in the tissue the higher the voltage needed to reach and destroy them. Physicists are experimenting to speed up the voltage. Already, with tubes twice as tall as a man, the level of 1,000,000 volts has been reached, creating cancer-killing rays equivalent to $20,000,000 worth of radium, yet the instrument costs less than thirty cents an hour to operate!

This is only a beginning. You may experiment with atom-smashers for this purpose, for they have already produced 3,000,000 volts. This would be more effective than radium or

X-rays for the high speed electrons, plunging into the deep-lying diseased tissue, do not injure the healthy cells at all. The method is still in its exploratory stage. Working in electronics and in bio-physics, you may be closing in on a solution to the problem, one of the most urgent that confronts medicine today. Maybe your name will be blessed by millions of sufferers from cancer.

You may design improvements in surgical aids like the radio knife which pours alternating currents of high frequency into the flesh around the wound, disinfecting and searing the edges, reducing bleeding, stepping up the healing process. You may develop more effective vacuum tubes to induce fever artificially, malaria germs having been used up until now for that purpose.

If it should be your good fortune to work with a physicist like Dr. Harvey C. Rentschler, director of research at the Westinghouse Lamp Division, you may be investigating the amount of ultraviolet radiation needed to kill bacteria. For this purpose you may use a type of luminous bacteria, found in sea water, that glows in the dark so that you will be actually witnessing their slaughter by ultra-violet rays from different angles. Ultraviolet, germ-destroying lamps are already installed in many factories, food-processing plants and chemical laboratories. This weapon promises to succeed where all others have failed in the battle against influenza, infantile paralysis and the common cold, as all these diseases are caused by a submicroscopic virus.

You might study the electron microscope with the object of developing its magnification still further. Physics early gave eyes to the medical research man with the invention of the microscope. Physicists then developed the ultraviolet microscope, reaching a magnification of 6000 diameters. That was the last word until the invention of the electron

microscope. This increased magnification to the unheard of level of 100,000 times. Looking at a single hair through this machine, you see what looks like a California redwood tree! For the first time, medical men can view the details of the submicroscopic world and viruses can be inspected as well as atoms. These new eyes may result in a revolution in bacteriology and medicine.

You may experiment with the new method of following the course of food after it is swallowed by making it radioactive. For example, you can bombard phosphorus in the atom-smasher and then give it to the patient who swallows it; on its way down, it gives out radiations which are picked up by a sensitive instrument and recorded. By this means, the doctor can tell just what happens to phosphorus in food, into what parts of the body it passes. You might improve this method of "tagging," which is still in its infancy. It has important applications in agriculture and bacteriology.

Again, you may be employed in manufacturing, even in fields not generally associated with physicists. Take the glass-making industry, for example. It is classed as a chemical industry. Yet, before the war, the Corning Glass Works in Corning, New York, employed twice as many physicists as chemists! This, however, is not to be wondered at as the foundations of the glass industry were laid in the nineteenth century by a physicist named Stokes. A consideration of the work of physicists in this industry in more detail will give you a clearer picture of the role of the physicist, not only in this, but in other industries.

In general, physicists test the qualities of the raw materials of glass from a physical viewpoint, improve manufacturing methods and help to develop new products. Employed in this work, you might analyze samples of glass in the laboratories; record and calculate the exact amount of light transmitted

and absorbed by the glass, not only for white light but for the colors of the spectrum, including infrared and ultraviolet. You might test for heat transmission and sound transmission and measure the resistance of the glass to heavy loads, to wind and to fire.

You may experiment with molten glass and make tabulations of its transparency under different conditions of heat, pressure and chemical treatment. You might develop new designs for radio bulbs, lenses used in airport beacons, bottles. Physicists, for example, are responsible for the glass in railroad men's lanterns. This glass does not crack in the iciest weather, even though it is heated on the inside. Physicists working with chemists in the Corning Glass Works introduced a remarkable glass in 1939 that was called Pyrex "Flameware." Heated to redness, it can be plunged into ice water without cracking. Again, it can be placed on ice and have molten iron poured on top of it and no damage will result. This discovery was the result of fundamental research into the properties of glass, research that started with no commercial application in mind.

As glass technologist, you may specialize in the manufacture of lenses, in which case you might be employed in the research laboratories of Eastern Kodak Company, the American Optical Company, or Bausch and Lomb, one of the largest manufacturers of lenses and optical instruments in the world.

In this work, you would conduct experiments with hundreds of "melts" to improve the physical qualities of lenses. Physicists on the staff of the American Optical Company make more than 1000 such experiments a year. Sand has hitherto been regarded as an indispensable prime ingredient of glass (silicon dioxide). Recently, however, a new type of glass has been developed without the use of sand. When

ground and polished, it is superior to other lenses in precision photography.

It is characteristic of the wide range of physics that in the field of photography, physicists are needed for the manufacture of glass; for the designing of lenses, so as to obtain the clearest definition and the widest field possible; for the designing of the camera; and also for the theoretical investigation of light (including infrared and ultraviolet rays) and its "refraction" through lenses and prisms.

Another advance in glass technology is the work of Dr. Nicoll of the Radio Corporation of America in his development of nonreflecting glass. He achieved this effect by coating glass with a thin film of calcium fluoride. Maybe it will be your good fortune to eliminate the annoying light reflections inherent in ordinary glass by a better method. Or you might improve on a new annealing treatment recently perfected by Dr. E. D. Tillyer, famous physicist of the American Optical Company. Annealing is the method of gradually cooling heated glass so that uniform transparency is maintained.

These are some of the problems that would face you as a physicist in the glass industry. Fundamentally, they are the same as in any other manufacturing or processing field. The object in any case is (1) to improve the quality of the product in any number of ways and (2) to simplify and improve production so as to lessen manufacturing costs.

While every field of manufacture has its particular attractions, it is possible that the electrical manufacturing industry is faced with the greatest variety of problems embracing many specialties in physics. Consider, for example, the different assignments you might receive if you were employed as a physicist by Westinghouse Electric and Manufacturing Company.

In electrical equipment, rust and corrosion of metal parts

is a major problem. You might therefore be assigned to work with chemists in handling physical problems concerned with developing new metals and alloys. Recent developments in this field have been the addition of 12 to 18 per cent of chromium to steel to make "stainless steel," nickel steel, etc.

Again, you might be assigned problems in mechanics. You may have to investigate the properties of production metals and measure elasticity and inertia.

You might specialize in heat problems, investigate its flow and develop methods of insulation against it as well as refrigeration, better heating methods, etc.

You may work in the field of theoretic optics. You would study the operations of ultraviolet and infrared lamps and seek to improve them. You would experiment with X-rays and spectrum analysis with a view of developing more effective X-ray machines and spectroscopes.

You might be assigned problems in electricity and engage in minute investigations of electronics and dialectrics. You may develop new electron tubes and study radar instruments. You might perform experiments in magnetism, electro-magnetic induction and electric arc phenomena.

Experimentation with new generators and power sources might be your special niche. In this field alone, advances in less than a generation have been amazing. Twenty years ago, for every kilowatt-hour of electrical energy, three to five pounds of steam were needed by steam power stations. Today, only one pound is needed, thanks to the discoveries of physicists in the electrical field.

Physics is one field of work in which youth is no bar to advancement and recognition. Milton Parker Vore was an assistant in the physics department at the University of Illinois when he joined Westinghouse in 1940. At the age of only twenty-eight, he won recognition for designing radio equipment to produce high frequency currents for "tin flowing."

Or consider Dr. C. Guy Suits, selected at the age of thirty-two as the outstanding young electrical engineer for 1937. A research physicist on the staff of General Electric, Suits produced heat of 18,000 degrees in a high temperature arc – 9,000 degrees hotter than the sun! Tackling the problem: how can such high temperatures be measured? – he photographed *sound waves* passing through the heat and developed this as a means of measurement.

Then there is Dr. John A. Hipple, another research physicist, who at thirty-three developed a spectrometer that can analyze the composition of a gas molecule one twenty-five-millionth of an inch in size and automatically record the composition on a chart in fifteen minutes! Ordinarily, it would take a half dozen chemists working together from one to two days of painstaking laboratory work to arrive at the answer.

What would be your duties when you first joined the staff of a large corporation, and what are the prospects of advancement and recognition?

You would probably be assigned routine work at first, such as testing materials and recording sizes, pressures and temperatures. How would you advance to a higher position? One way might be the method of Dr. Joseph Slepian who had a Ph.D. from Harvard when he joined Westinghouse. It was not long before foremen began interrupting his routine work with problems that needed solving. Knowledge and ability have a way of getting known along the "grape-vine route" in a plant, and the new man, it was whispered, knew his stuff.

After several months, Dr. Slepian discovered that there was a vacant desk in the main research office. He picked up his books and papers and just moved in. Nobody seemed to object. He remained, lost in his theoretical investigations of electric power systems.

Dr. Slepian was too busy with his investigations to seek



A laboratory technician at Western Electric tests for chemical content in cable sheathing. Her results must be accurate to within two-thousandths of one per cent.
(WESTERN ELECTRIC)



Routine analysis of product purity in Dow's main analytical laboratory

(DOW CHEMICAL COMPANY)

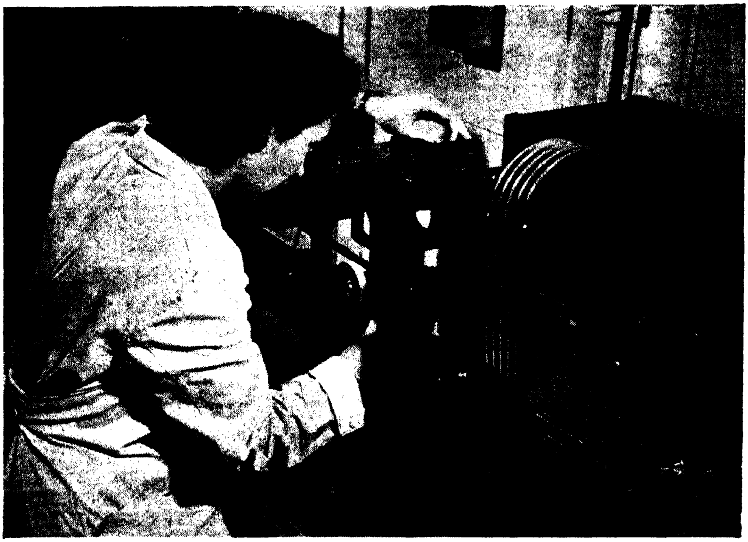


Young chemist makes delicate adjustments before testing copper. Her work is part of continuous program of laboratory analysis of copper content of scores of copper alloys used in telephone system.

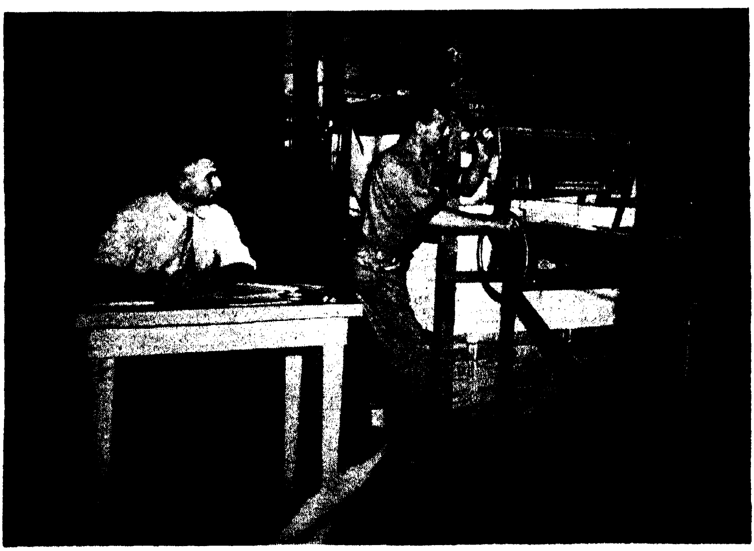
(WESTERN ELECTRIC — PHOTO BY HOLMES I. METTEE)



[illegible] test runs on engine being run up in a [illegible] at Wright Aeronautical Corporation.



A college graduate with chemistry and physics major, this laboratory technician uses X-ray machine to photograph engine parts.
(WRIGHT AERONAUTICAL)



Research workers temper bended glass in the Glass Research Laboratories of Pittsburgh Plate Glass Company.
(PITTSBURGH PLATE GLASS COMPANY)

out fame, but fame came to him. His "De-ion" circuit, given its first public test in 1927, ushered in a new era of high power transmission into industry.

If you have what it takes, you need not worry that you will be buried in obscurity and hidden by the big names of a corporation. Speaking of his experiences later, Dr. Slepian said they proved that "a company, no matter how powerful, is still flexible enough to give way to a scientific worker who wants to make his own niche."

Physics is a profession for scholars rather than money makers. However, if you are interested in research, you need not resign yourself to the classic picture of poverty, deprivation and lack of recognition that were so graphically shown in the motion picture, *Madame Curie*.

This is well illustrated by the experience of Dr. Edward Uhler Condon, a former assistant professor of physics at Princeton University, Dr. Condon was not interested in practical, money making inventions. His passion was hypotheses, especially the quantum theory. You might have expected such a man to end his days in the cloistered academic world of books and blackboards, disregarded by industrial concerns and big business.

Such, however, was not the case. Instead, he was appointed associate director of research by no less a hardheaded and practical engineering company than Westinghouse! One of his main duties today is directing the work of research in the field of pure science.

Today is a far cry from 1840 when scientists were looked upon askance as woolgathering dreamers. It is also a far cry from the days of Pasteur and the Curies. As a physicist, there are two fears you need never have: the fear of not being needed and the fear of not being recognized for your achievements. The research scientist has won his long battle and is recognized, not only by the general public and government

authorities, but also by the boards of directors of giant corporations. The reason for this is obvious; the debt that industry and public health owe to the physicist is attested by every manufacturing and power plant, household, hospital and transportation system in the United States.

Chapter VI

PHYSICS: JOBS BASED ON THIN AIR

WILL it rain next week? Billions of dollars hinge on the answer. There is the manager of the Brooklyn Dodgers. He must know before he makes up his baseball schedules. There are the big movie studios, planning to go out "on location" with expensive casts. There are the executives of hydroelectric plants. They must know because a heavy rainfall means less need for other sources of power. Thousands of officials in all fields of activity join the farmer in looking up anxiously at the sky and then – consulting the meteorologist.

Meteorology is the science of weather and climate, based on analysis of atmosphere, winds, clouds and barometer readings. Training in physics and mathematics is basic. Within the last twenty-five years, this science has become so exact and dependable that the weather forecasts of private meteorological concerns have been found correct 97 times out of 100.

The day is not far distant when every large manufacturing firm may have its own weather expert, for business is depending increasingly on meteorology for decisions involving the weather. One example is a large candy company that was losing thousands of dollars because its candy, shipped all over the country, melted in transit when the thermometer rose steeply. Today, before shipping its sweets, it consults the Weather Bureau to make sure that no hot spell is in sight.

Forest Service officials depend on the weather man to tell them when forests are becoming dangerously dry. Operations may then be suspended for safety's sake. Special

forecasts of wind and weather are made especially for fire fighters.

The meteorologist's hurricane warnings have also saved millions in lives and dollars. In 1900, when this service was not in existence, the Galveston hurricane cost 6,000 lives and great property loss. In 1941, a hurricane struck again. This time, the people were prepared, thanks to the Weather Bureau, and only four people were killed, one by drowning.

During the war, the army started its own air force weather research center and Dr. Krick, whose Krick Industrial Weather Service had been keeping the biggest corporations in the country posted on weather conditions, became Major Krick, in charge of the center. Meteorology soon became a powerful, secret war weapon, forecasting a week in advance whether conditions would be favorable or unfavorable for the movement of troops.

As a research physicist in meteorology, you may develop new methods and instruments to obtain weather data. You may measure the amount of sunfall or ultraviolet with an instrument dubbed the "electronic eye," made by Westinghouse engineers. This resembles a long, oversized radio tube. At the upper end is a flat, metal button about the size of a half dollar, surrounded by wire electrodes. Ultraviolet rays from the sun, striking the button, release a stream of photoelectrons to the electrodes in currents so tiny that they measure one-millionth of a watt in power. From the electrodes, the electrons flow to a condenser. A sensitive relay trigger registers a sharp click every time the condenser discharges its quota of ultraviolet. By recording the number and frequency of these clicks, the meteorologist has information that helps him to forecast bright or cloudy days, as well as rain or snow.

You might operate these instruments in one of the solar observation posts planned throughout the country by the

United States Weather Bureau. Your ultraviolet measurements would be sent to medical men as well as farmers and agricultural colleges. These findings aid doctors in their investigations into the effects of ultraviolet rays on human health. That they help to cure tuberculosis and rickets is well known, but lack of sufficient data regarding the amount of solar radiation up until now has hampered medical investigators.

Your data may prove of value also in agricultural studies and crop surveys. What effect, if any, have ultraviolet rays in the upper stratosphere upon weather conditions? The electron eye may see through this important question and thus make forecasting more efficient, for comparatively little is yet known about the higher regions.

You might develop instruments like the radiosonde, which looks like a box camera. Attached to a free balloon, it is lifted into the stratosphere, twelve miles up. As it travels, it registers wind velocity, icing conditions, etc., and the data is broadcast by radio to an automatic recorder on the ground. It goes up so high that the balloon finally bursts and the sonde comes parachuting down to earth safely.

Until very recently, human blonde hair was used in this instrument, as hair is very sensitive in reacting to variations in moisture. Now a coated plastic is used instead.

The sonde bears the label of a return address, so that it can be sent back to the station from wherever it lands. This electronic weather man furnishes meteorologists with data on temperature, pressure and humidity at different altitudes in various parts of the country. On the basis of this data, they are able to make more comprehensive and dependable weather predictions, as they correlate it with information from other sources.

As a government meteorologist, your work would consist mainly of entering records, making calculations, and charting

weather maps. Your salary might begin at $1400 to $1800 with the grade of "junior observer." The highest position is that of principal meteorologist with a salary of $4000 to $5000 a year. All weather bureau positions are on a civil service basis.

You might become a private air line meteorologist. In this case, the very lives of passengers may depend on the accuracy of your forecasts. It is because of the special responsibility of this work and the great expansion of the airplane and air line industry in recent years that salaries start at a higher level than for government jobs: $150 to $200 a month. To qualify, you would have to have at least two years' experience in meteorology. As air line meteorologist, you would receive periodic reports on weather conditions, analyze and interpret them and relay your forecast to air pilots and air line officials.

What are the special qualities of the air line meteorologist? You must be trained to read storms and rainfalls in maps and diagrams. You must be able to think fast and accurately, without losing your head, for a sudden change in weather may mean the cancellation of an air trip and yours will be the responsibility for the decision. You must be prepared to rough it a bit. Your work may involve irregular working hours and sudden trips in zero weather into out-of-the-way places.

To qualify, you must have a college education and training in a graduate meteorology course. During your college years, it is recommended that you take as much mathematics and physics as possible. For the position of junior meteorologist, you would have to study synoptic and dynamic meteorology as well (the science of fitting different and changing reports into a general pattern).

Meteorology is not confined to weather forecasting. You might become a climatologist and assist the soil conservation service. You would study geography and climate as they effect erosion of the soil and thus help to eliminate this evil

which is costing farmers millions of dollars every year in avoidable waste. As junior soil conservationist, you would work for the government at a salary that starts at $2000 and rises to $6400, when you became principal soil conservationist.

You might be attracted to astronomy, another occupation based on light rays and infinite space. For this select profession, you will need not only a B.A. but also a Ph.D. Your training period would be as long as the medical course. In addition to physics and mathematics, you are advised to take chemistry, engineering, photography and optics in all branches. Foreign languages are also important.

Astronomy is a profession for scholars and research-minded students exclusively. It offers little in the way of material inducements, for no astronomer ever became wealthy from planet study, top salaries being roughly equivalent to that of college professors. Opportunities for jobs and promotions are not as great as in other fields in physics owing to the limited number of observatories. In the whole world, there are less than one thousand active, professional astronomers, although many thousands of amateurs in this country have constructed their own telescopes for stargazing purposes. For this reason, would-be astronomers become teachers and combine teaching with research, all the time hoping for appointments to observatories when vacancies occur.

While college training is indispensable if you wish to become a professional astronomer, the self-tutored amateur can still break through to fame as a stargazer. This happens very rarely, it is true, but when it does it illuminates all the more vividly the qualities that make for success in a career in science.

Consider, for example, the strange case of Clyde Tombaugh, poverty-ridden child of a tenant farmer of Kansas. When he was twelve, his father bought a cheap lens, made an eyepiece out of an old magnifying glass, and rolled up an oil

cloth tube. Clyde gazed awe-struck at the heavens for the first time through this "telescope."

From that time on, he devoured books on astronomy at the public library. When he went to school, he was dubbed "Comet Clyde" by his schoolmates because of his fanatical stargazing. He husked corn for a neighbor at $1.00 a day in order to raise enough money to buy materials for a new reflecting telescope. After months of tedious polishing, he finally had the telescope finished. That night he looked through it and saw the polar cap of Mars. Enchanted, he spent the entire night with the instrument.

Clyde's passion for the stars led to superhuman labor. To obtain constant temperature essential to grind a better telescope lens, he discovered an underground cave was necessary. So, singlehanded, Clyde dug a cave with a pick and shovel during the hours between farm chores; it was 24 feet long and 7 feet deep. Then he cemented the floor, walls and ceiling and set to work to grind the lens for a new nine-inch telescope. For the mounting, he used an old cream separator and discarded farm machinery. Through this instrument he saw the network of the canals at Mars. Clyde sketched them and sent the sketches, along with other planetary maps, to Lowell Observatory, at Flagstaff, Arizona. To his amazement, he received a reply from Dr. V. M. Slipher, the chief astronomer, offering him a job to help search for an unknown planet!

Clyde reported for work a few days later. Each night he loaded holders with plates and set them in the photographic telescope. With a seven-inch visual telescope, attached to the larger instrument, he focused on the "guide star" for the evening's work. Each plate was exposed for an hour, and every sector of the teeming sky had to be patiently explored in a search that might have taken twenty or a hundred years.

In the daytime, Clyde studied the plates with a "blink

comparator," a device in which two plates of the same region of the sky, photographed several nights apart, could be placed. This enabled him to tell the relative positions of the stars and planets.

Thus passed the summer of 1929, then the fall. The observatory was unheated in winter, but Clyde stuck to his instruments with freezing hands. Then came an afternoon in February, 1930. Clyde caught the flicker of something new racing across the sky. Excitedly, he reported the news. Weeks of careful checking and observation followed. By March 13, the newspapers got the story: a twenty-four year old Kansas farm boy had discovered a new planet, now called Pluto, after many astronomers had denied the possibility of its existence. Pluto is so far distant from the sun that it takes two and a half centuries for it to make one revolution around it.

For this discovery Clyde received a medal from the Royal Astronomical Society, but more important still, was the offer of a science scholarship from the University of Kansas, for this meant a college education – the fulfillment of a dream. While studying for his bachelor's and then master's degree, Clyde continued his stellar investigations. He made photographs of every object in the sky of the seventeenth magnitude or greater: this meant 2000 photographic plates and 60,000,000 stars! At thirty-eight, this farmer's son, through courage, self-education and singleness of purpose, has become one of the world's most distinguished astronomers.

Space bears light rays which, reaching your eyes, enable you to forecast the weather if you are a meteorologist, or to record the movements of planets, if you are an astronomer. But space transmits many other types of radiations, some of which have opened new fields in physics and created new careers. Radio, for example. This giant industry is the fruit of decades of research in radiations. In the words of Dr. Alfred Goldsmith, consulting radio engineer: "Radio com-

munication is an advanced application of various principles of pure physics." He added that it involves optics, as in television; acoustics, electronics and a theoretic knowledge of electron optics (that is, the new conception of light not only as a series of waves but also as the projection of electrons).

The amazing growth of the radio is one of the marvels of modern times. Soon after DeForest's vacuum tube was perfected in 1921, manufacturers rushed into the market and sold $6,000,000 worth of parts and complete sets. The following year, 100,000 complete sets were sold. The number rose to 7,000,000 in 1936! The widespread use of this invention transformed the means of communication, entertainment and education. Yet the world may be on the threshold of a further revolution caused by that other space-destroyer: television. The expansion of the television industry means hundreds of new jobs for physics-trained men and women.

Experts predict that the television industry will go through a period of tremendous growth after the war. This is indicated by one estimate that in five years, service will be available to two-thirds of the population and 2,500,000 sets a year will be sold, as compared to the 10,000 television receivers in the hands of the public in 1944.

Ten years after the war, according to this estimate, there will be more than 1,000 television stations in the United States; 25,000,000 receivers will have been sold; television will have become a $3,000,000,000 industry and will employ about 65,000 people directly.

Already projection television has been perfected. The image can be thrown on a wall screen exactly as in a movie theater, with good illumination and definition. One manufacturer plans to manufacture and sell these sets after the war for less than $300.

You can obtain technical training for radio engineering at radio schools scattered throughout the country. You should

take this course if you wish to do research work with manufacturers of electrical communication equipment, etc. Many colleges give credit for radio and nearly every engineering college in the country offers one or more courses in its electrical engineering department in radio engineering, including television as well.

For television engineering, you will have to be a radio engineer first. The technique is much more complicated than that required for radio. Courses for training are not well established as yet, because the industry is still in its stage of infancy. It will expand rapidly in the postwar era, however, as shown by the plans already laid for the building of many new television broadcasting stations. Nor is television limited to the entertainment field. It can send a picture through darkness or peasoup fog to the screen of a battleship or airplane, for example, or even through electric telescopes in magnified form to the eyes of observers!

Radio communication and television are not the only uses of the science of radiations. You may study the applications of radio waves in industry — a new development. One machine broadcasts radio waves from a ten foot length of coiled copper tubing, at the rate of 200,000 a second. The waves strike a plate of tin and fuse it, producing a smooth, shiny finish in one tenth the time formerly required. The machine consists of vacuum tube oscillators which make transmission possible in radio stations. It does away with the necessity for ponderous furnaces or vats of hot oil that have been used up until now in tin-fusing.

The same education and training may lead you to the development of high speed X-ray machines to photograph objects moving at terrific speed. War necessities have already resulted in instruments that take such accurate pictures of golf and tennis balls in the split second they are struck that the inner structures are plainly revealed. Your services may

be in demand by army ballistics experts who want pictures of bullets in mid-air or while passing through the barrels of guns.

How would you take these pictures? By sending a barrage of X-rays through the steel barrel. Recently, Dr. Phillip C. Michel, of the General Electric Company, announced that electronic equipment had been perfected which can measure the speed of projectiles to the one-one-hundred thousandth part of a second. Already in use at the Ordnance Research Center proving grounds at Aberdeen, Maryland, it automatically measures the speed of a magnetized shell fired through a series of electric coils spaced 100 feet apart and records it on an electric typewriter in tabulated columns. Or you might work with a machine like the fulchronograph, introduced in 1939, which gives a complete record of a lightning stroke, measuring not only its maximum value but also the volume of energy expended. Such data may result in devices that are lightning-proof.

You might specialize in radar, called the greatest secret weapon of the war. The discovery and development of this instrument was as dramatic as the war itself.

In 1940 Hitler turned to night bombing of England. The RAF pilots, outnumbered by ten to one, had to locate the black ships in the dark and intercept them – an impossible task before 1935. They succeeded, thanks to radar, and Hitler had to give up his aerial attacks. It is thus possible that radar, as much as any other weapon, saved England from destruction. Physicists had been developing this instrument for many years but it received its first secret test in 1935 in a quiet English lane, near Daventry, where a battered truck was parked. Inside, was physicist Robert Alexander Watson Watt, a few other physicists and two young women laboratory assistants who could keep a secret. An RAF plane kept appearing and reappearing in the sky. Could the instrument

in the truck detect the approach of the plane? The answer was yes. Like a moving finger, it kept pointing to the plane wherever it flew!

Thus did radar make its appearance. How does it work? It sends out short radio waves that travel with the speed of light, straight through fog, smoke, rain or snow. When they strike a ship or airplane, they bounce back and flash their findings to the radar plotting board. Radar records the altitude, speed and course of approaching planes. The new weapon is immeasurably superior to the old-fashioned sound detectors of limited range, for the radio waves travel a million times as fast as sound waves.

Experimenting with radar, you may seek to improve it still further for peacetime uses. With this magic eye, ground services can be kept automatically in touch with moving airliners. Radar keeps them advised of mountains or other obstructions ahead. Ocean liners need no longer grope their way through a fog fearful of icebergs, for radar keeps them informed at all times of approaching obstacles even in the thickest gloom.

You might specialize in optics. This fascinating field covers the vast range of vision from the tiniest bits of matter to the farthest reaches of space, representing the electron microscope at one end and the colossal telescope in the Mount Wilson Observatory, at the other. It embraces optometry, the science of optics applied to human vision, as well as the design of optical devices, like the spectrometer, and polaroscope, used to analyze the composition of materials and to measure defects.

You would study the wave theory of light, also polarized light. You might work with chemists and develop substances like polaroid, an amazing, transparent film having a trillion crystals, lying parallel with each other, in each square inch. Imagine a vertical slit in a wall with rope passing through it.

Now imagine waves moving along the rope in all planes. Only the waves vibrating in the vertical plane would pass through the slit. That is the effect of polaroid: light passing through it can vibrate only in one plane.

Through polaroid glasses, you can gaze into a blinding fish pool on a sunny day, look right through the glare and see the fish clearly. But that is only one of the uses of this magical substance. By the use of two or more polaroid films with their "slots" at different angles, light can be dimmed or totally eclipsed simply by revolving them. That means elimination of the glare of automobile headlights if the film is used both on the headlights and on the windshield of each car! But that isn't all, either. Using a colorless cellophane, you can create brilliant color harmonies, valuable for advertisers and stage designers.

Again, used by movie goers as a pair of spectacles, polaroid makes stereoscopic movies in full color and objects leap out at you from the screen more than life-size! Sending polarized light through glass objects, you can immediately locate strains and stresses, which appear as shadows in the affected areas. These are just a few uses of this scientific marvel.

You might do research in optometry, the new scientific profession. There are some 18,000 registered optometrists in the United States, only one to every 7,900 people, compared to one physician for every 850 people. Three universities give courses of three to four years, requiring high school diplomas as prerequisites. After graduation, optometrists must pass special state board examinations in order to be licensed, just like dentists or physicians.

Problems in optometric research that might engage you would be improved plastic contact lenses, which are inserted between the lids so that no frames or mountings are needed and improved aids to those who are near-blind even with glasses, like the magnifying "telescopic spectacles." In the

optometry courses, you would study geometrical optics (the mathematical study of light passing through lenses and prisms), physiological optics (optics applied to the eyeball), the anatomy of the eye and eye diseases.

Radiations and vibrations in space thus result in thousands of scientific jobs and careers based on the study of light, radio, magnetic waves, heat waves. You could spend a lifetime studying just one kind of radiation. But that isn't all. The air itself, strangely enough, is the foundation for a solid career that has fascinated every man, woman, and child for ages – aviation!

Ever since Leonardo Da Vinci experimented, in the fifteenth century, with contraptions fashioned like the wings of birds, man has been chafing at the necessity of being grounded. The first actual flight was performed by a Frenchman in 1873 who used a balloon filled with hot air. He rose to a height of 75 feet. It was not until 1903 that modern aviation won its wings with the successful flight of the Wright brothers in a plane powered by a 20 horse power gasoline engine.

From a scientific curiosity, the airplane has become a necessity and one of the chief means of travel and transportation, to say nothing of its importance in war. This expansion is largely the work of physicists who through research developed faster, lighter and safer aircraft of all kinds and types.

Specializing in aviation research, you might be employed in the laboratories of the National Advisory Committee for Aeronautics. This organization is famous throughout the world and has done much to make the United States the world's leader in commercial aviation. You might be one of a staff of 450 experts at Langley Field, Virginia, where the laboratories are located. You would co-operate with engineers and technicians, drawing charts, making models and calculations involving wind resistance and engine power.

You would seek to improve plane design as well as speed and efficiency.

For special training in aviation theory and design, you might attend one of the private commercial aviation schools located all over the country. They give courses for aeronautical engineers as well as air line administrators. For design and aeronautical research, these engineering courses, which are highly advanced and theoretical, are essential.

A number of colleges offer courses in aeronautics, some giving a degree in aeronautical engineering as one of the electives, if you major in mechanical engineering. Typical subjects taught are aero-dynamics, airplane design, engine design, airplane stress analysis, propeller theory and design, aeronautical meteorology. Now you understand why you are urged to take as much physics and mathematics in high school as possible!

From a vocational viewpoint, the future possibilities in aviation are tremendous. In 1939, for every certified plane in the United States, there were more than two certified pilots. Since then, interest in aviation has been further intensified by war developments, and 500,000 civilian airplanes are expected to be in operation after the war. According to one estimate, air transport is expected to carry four to five times as many passengers five years after the war ends, as in 1941. New discoveries and developments like the rocket plane and helicopter have already resulted in plans for a greatly expanded air service during peacetime. This will increase the need for thousands of research scientists and technicians for the creation of improved models.

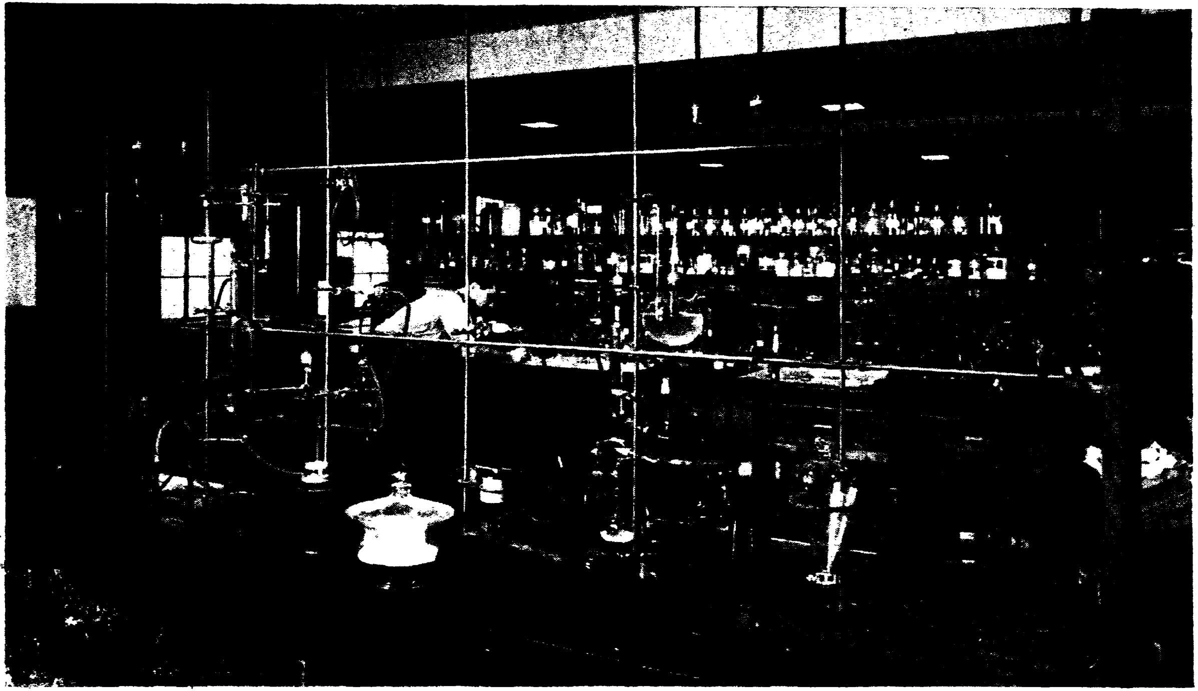
Consider the helicopter. Hardly more than a curiosity before the war, it has emerged as a respectable air craft in its own right. Transit lines have already applied to the Civil Aeronautics Bureau for networks of "air bus" services. Helicopters will land atop bus terminals and in small fields, with



A veterinarian at the Department of Agriculture's Animal Disease Station, Beltsville, Maryland, injects a guinea pig with Brucella vaccine to prevent Bang's Disease. (U. S. CIVIL SERVICE COMMISSION)



Junior Chemist in the Bureau of Home Nutrition and Home Economics extracts Carotene from dehydrated foods.
(U. S. CIVIL SERVICE COMMISSION)



Research worker makes notes in home of Allymers, new name for plastic monomers created in Columbia Chemical Laboratories of Pittsburgh Plate Glass Company, Barberton, Ohio.

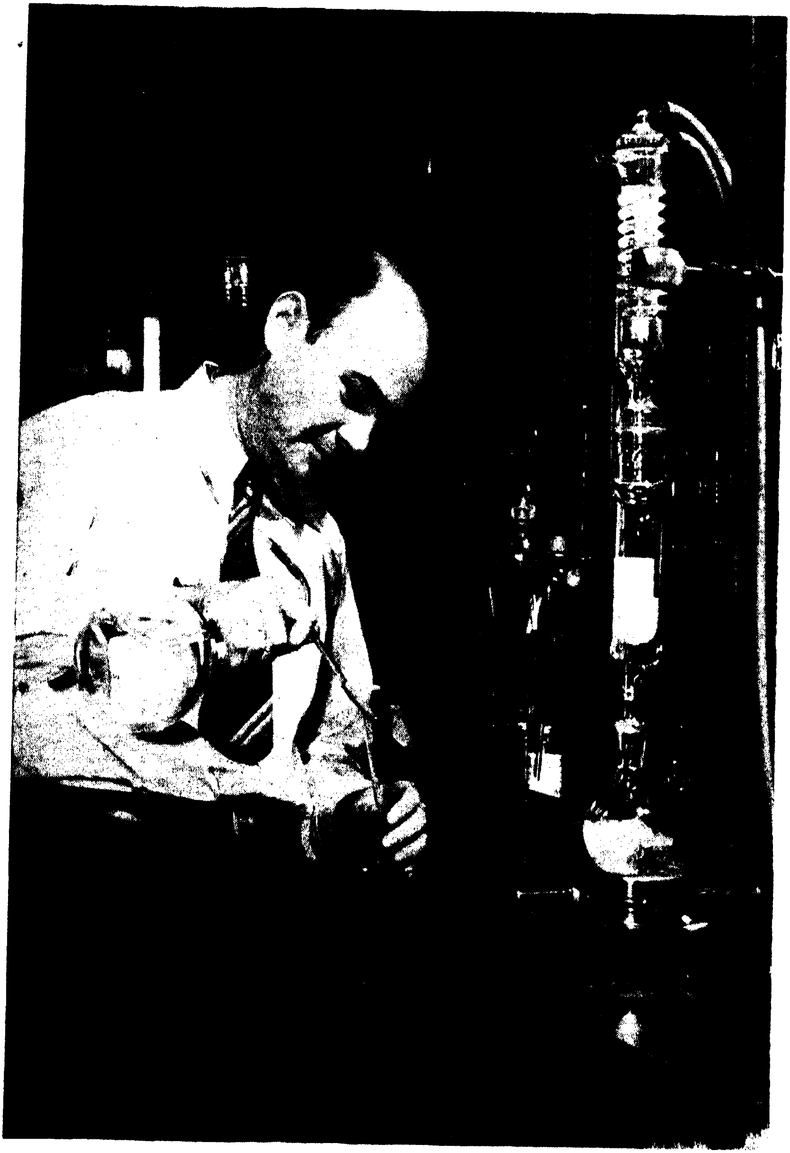
(PITTSBURGH PLATE GLASS COMPANY -- PHOTO BY GOTTSCHO-SCHLEISNER)



Chemist in Fish and Wildlife Service, Department of Interior, examines culture slide, a step in process of developing substitute for Japanese Agar, a gel obtained from seaweed.
(U. S. CIVIL SERVICE COMMISSION)



Chemist in Agriculture Department fills Soxhlet extractor (in hood) prior to extraction, by distillation, of toxic substances from certain plants for use in insecticide manufacture.
(U. S. CIVIL SERVICE COMMISSION)



Chemist of the Food and Drugs Administration analyzes American cinchona bark for its quinine and alkaloid content.
(U. S. CIVIL SERVICE COMMISSION)

passengers, mail and freight. The Greyhound Bus Corporation plans the use of helicopters in its expanded postwar system of 88 routes, covering over 49,000 miles. Applications have been made for helicopter routes to Cuba, Mexico, and the Panama Canal Zone. Transatlantic routes have been planned by British steamship companies. Extensive use of gliders is also planned.

Aviation research is not a draftsman's job alone. Suppose you are designing a plane that will travel faster and higher than any other plane. You would have to duplicate the conditions of the stratosphere eight to ten miles above the earth, where the temperature is 67 degrees below zero, and subject your new model to these conditions. You have spent years in calculations and experiments, say, and have at last perfected your new model. Now to test it thoroughly and see how it would behave under the actual conditions of flight in the stratosphere.

You order it suspended inside the test chamber of a high altitude, high speed, "wind tunnel." Then you give the signal: more than 4,000,000 cubic feet of air a minute rushes into the tunnel, propelled by two counter-rotating propellers, mounted hub to hub in the 19-foot section of the tunnel. Two motors, 11 feet high, are connected to the propellers by long shafts that pierce the tunnel walls. These motors, together, produce the power of 500 automobile engines at full throttle!

The motors can be slowed down and the roar in the tunnel becomes a moderately stiff wind. On the other hand, you can test your model with a greater than 600 mile-an-hour hurricane, screaming its way into the tunnel at a speed no present day plane can match in level flight.

[illegible]ch for the plane itself. You might also design a test [illegible]ber for the "crew," like the Strato-Trainer, and watch their reactions through thick plate glass windows, as low

pressure atmosphere equivalent to that existing at an altitude of 50,000 feet, is produced in four minutes. The "guinea pigs" in the experiment will be protected with warm clothing and oxygen tanks.

Gasoline boils at the sub-zero temperature of the stratosphere. This is only one of the problems you would have to solve in designing for high flying planes. Another problem is the drop in the engine's horsepower, due to falling air pressure, from 1000 to 200 as the plane reaches the stratosphere. In addition you might experiment with aircraft like the rocket plane in which new aeronautical principles are applied. You may develop revolutionary changes in design or operation that would make the rocket plane itself appear as outmoded as the Model T Ford of 1910!

It takes from four to seven years to design a new type of airplane. Continual study and experiment are necessary – and also a knowledge of electrical engineering, as electricity has replaced hydraulic operation. Today, landing gear retractors as well as shutter doors are operated by motor.

You might be designing flying clippers for commercial use after the war, carrying 150 passengers instead of the prewar 24, with engines totaling 12,000 horsepower instead of 6,000. These clippers will fly from the Atlantic seaboard to Europe in ten hours.

Employed by the Air Transport Association, representing all the airlines, you may work with engineers on specifications for different types of improved planes for short or long hauls, with accommodations for passengers varying from 25 to 150.

You might develop a "skyfreighter," an eight-engined flying boat weighing 400,000 pounds and capable of carrying 120,000 pounds of cargo. You may experiment with improved airplane engines furnishing more than the present capacity of 2,200 horsepower (stepped up during the last

few years from 1,200). Another development planned is "flying boxcars," carrying cargo exclusively and hurrying it at low cost across the continent.

On the other hand, you might create luxurious de luxe airliners, with improved air-conditioning; plane-to-ground radio and telephone service for passengers; receivers for radio broadcasts; observation and cocktail lounges and kitchens to supply fresh-cooked meals. Aeronautical engineers have designed "pressurized" cabins to reduce discomfort in bad weather and in high altitudes.

A few more indications of the ways in which physicists are transforming aviation: flying wings are being designed so as to carry pay-loads; the rocket principle of propulsion is being applied experimentally to commercial aircraft; and the "magnetic tailwind" has been invented. This is an instrument that enables a pilot to determine the power output of his engines 10 to 15 times more accurately than with the present method.

Meteorology, radio, optics, aviation – these are some of the fields in which careers based on physics are open to you – careers that were founded by men and women who had a love for research rather than an interest in material applications.

When you watch the Coolidge X-ray tube in operation, you are likely to think that its inventor is essentially a practical man who always adapted his experiments to the needs of industry. Yet it was this same inventor, Dr. William C. Coolidge, who wrote: "I have acquired a love for fundamental research, for the study of natural phenomena for its own sake and regardless of where it might lead." It was not practical considerations but love of research that was primarily responsible for the high-powered X-ray tube that bears his name.

This is true not only of the creation of new instruments

but also of improvements. Consider, for example, the achievements of Dr. Ernest E. Charlton, who solved the problem of making 1,000,000 volt X-rays portable. Referring to the improved X-ray machine designed by him and his associates, Dr. Coolidge said: "The research work involved occupied the full time of an average of six men for a period of four years and this, starting of course, not from scratch but with full knowledge of the X-ray equipment of before."

Research based on thorough training led these men to improved X-ray tubes. In your case, it might lead to improved airplane engines or discoveries in optics, radio, television, meteorology, or power sources. At any rate, opportunities were never brighter than they are today. There is not a department of physics that is not simmering with new developments and discoveries, stimulated by the demands of scientific warfare. And most of these are the achievements of young men.

Physics is one field of science that welcomes youth with open arms. Of a total of 10,004 scientists in this field, 3,464 (or 35 per cent), were reported in 1943 to be twenty-nine or under. Said *Science News Letter* (April 8, 1944): "Atomic physics, so important to the war that all recent developments in this field have been kept from publication until after the war, is the exclusive domain of very young men. Research in this field would be practically ended if all young men were drafted and sent to combat units. If all those qualified in certain important fields of radio were to be withdrawn from this field, about 80 per cent would be taken, it is estimated."

It is difficult to believe that organized research in physics started only twenty-five years ago! In this time, physics has revolutionized man's knowledge of matter, energy and the universe and has led to transformations in industrial technics. The results of these advances both in pure and applied physics have been to create thousands of occupations un-

known before. These require specialized training in fields as diverse as electrical surgery, oil prospecting and airplane designing. You cannot peer into the future but of one thing you can be sure: training in physics will be fundamental for thousands of careers and jobs, not only existing but waiting to be born.

Chapter VII

BIOLOGY: CAREERS IN PLANTS

FEAR gripped the growers of sugar cane in Louisiana. Their industry was being destroyed by unseen saboteurs. Production fell from 250,000 tons of sugar to 50,000 tons, as a baffling plant disease ravaged the cane, leaving withered stalks in its wake – and bankruptcy to the growers.

Their cries for help reached the Department of Agriculture. Plant specialists decided there was only one way out: they would have to discover a kind of sugar cane that was proof against that particular disease.

Plant explorers were sent to Asia. At last they discovered what they were looking for, in Java. They made "crosses" between this specie of cane and the American kind. The result was a new sugar cane that could be grown in America and was immune to the disease. An industry that brought in $15,000,000 every year was saved from ruin, thanks to the biologist.

Prevention of plant disease is only a small part of the biologist's work. Biology, the science of living things, is as wide as life itself and embraces scores of activities, jobs and careers. It includes entomology (the study of insects), genetics (the study of heredity), anthropology (the study of mankind in different ages), botany (the study of plant life), ornithology (the study of birds), zoology (the study of animals), pathology (the study of diseases, in plants and animals), bacteriology (the study of germs and single-cell animals). It embraces medicine, gardening, lumber engineering, tree surgery, pharmacology, public health, sanitation, soil conservation, forestry, nursing, nutrition, child welfare,

administration of aquariums and museums, and a host of other sciences and careers.

In normal times, about 300,000 people in the United States hold down jobs that require training in biology. All but 20,000 are employed by government agencies, whether federal, state, or city. On the pay roll of the Department of Agriculture alone are 67,000 biology-trained men and women.

If you become a biologist, therefore, you would probably be a government employee but you would have an amazing variety of occupations from which to select your career. You might specialize in the animal industry, the dairy industry or the plant industry. You might concentrate on the chemistry of soils or home economics or forestry or plant quarantine.

You could do research in foods, drugs or insect-destroying chemicals in the laboratories of the Food and Drug Administration. On the other hand, you may decide to study fishes, their breeding habits and preservation, in which case you would work in the Bureau of Fisheries. Perhaps you would be more interested in the biological effects of chemical warfare and work as research scientist for the Department of War. Are you attracted by studies of Indian life as a branch of anthropology? You could be employed as biologist by the Office of Indian Affairs which administers Indian reservations.

For medical research, you would work in the United States Public Health Service, in its National Institute of Health division. This division has nine departments of specialized research covering most fields of physical and mental diseases. Medicine occupies a large sector of biology and is closely allied with sanitation engineering, mental hygiene and nutrition.

Consider the broad field of agriculture and plant life. It was biology that raised farming from a primitive hit-or-miss

adventure in food raising to a scientific occupation. This is shown by statistics. When the United States was founded, it was by no means certain that people would be able to raise enough food to live on. About 19 out of every 20 people spent all their time producing this important commodity. By 1840, the proportion changed to 16 out of every 20. Today technology and biology have combined to raise the output per cultivated acre in the United States to such a level that only 4 out of every 20 people are engaged in agriculture, and yet food production has reached such high levels that the famine of backward countries is a thing of the past.

How did biologists help achieve this result, which the eighteenth century peasants would have regarded as a miracle? By doing two things: (1) increasing the yield of crops so that the farmer could grow a larger and better harvest for each acre he sowed and (2) killing off insects and diseases that have always hung like clouds of disaster over fertile fields.

To cope with the problem of improving the crops of fruits and vegetables, you would have to be trained in chemistry as well as botany. Plants are food for man; have you ever asked yourself: what is the food of plants? You would study this problem and learn how a plant absorbs carbon dioxide from the air when the sun is shining, just as you breathe in oxygen, and how it is transformed into plant substance.

Plants draw nourishment from the soil also. You would study the chemical composition of the soil. Some soils are deficient in iron, sulphur or copper. You would discover that certain plants and crops grow poorly in such soil because of the deficiency.

In certain farm regions of Florida, children were suffering from anemia. Why? There was no apparent reason for they ate the prescribed food for healthy youngsters. Biologists investigated. They came upon an interesting fact: cattle in the

same region were wasting away from "salt sickness." They knew this disease is caused by lack of iron in cattle feed. So they analyzed the soil and found it was deficient in iron. This explained the anemia which resulted, and also illustrated the importance of soil chemistry.

You may be called upon to investigate low yields of alfalfa in the great regions of the Northwest. You might select samples of the soil and make quantitative analyses in your laboratory. What vital element is missing? Sulphur, perhaps. You would add sulphur compounds to the soil and compare the alfalfa yield to that of untreated soil. The yield has been increased as much as five fold by this method.

Perhaps you would discover that iron is present in the soil but in an insoluble form, so it could not dissolve in water and be drawn into the plant through the roots. That was what was wrong with the pineapple crop in Hawaii. You might have to devise a method like spraying the plants with iron sulphate so that iron will pass directly into the plants through the leaves.

The chemurgist applies chemical treatment to waste materials to transform them into valuable products. As a plant specialist, you might apply chemicals to plants and soils for another reason: to control their growth and modify their characters. This is a new science that has been developed only in the last thirty years. How does it work? Here are plants that respond poorly to light. You may transplant them to your laboratory and treat them with different organic chemicals. You will find one that, applied to the plant, makes its leaves turn to the sun for the first time! On the other hand there is a plant with roots that are too short. By applying the proper chemicals, you might cause them to lengthen.

You can change the structure of the plant itself by this method. Look at a section of it under the microscope and measure the average length of the microscopic cells. After

chemical treatment, measure it again and you will find the cells have grown longer! You can step up the growth of plants or slow it down by the magic of chemicals.

These complicated organic compounds are manufactured both by plants and animals. You might perform experiments with them in the biological laboratory, for many questions in this new field are still unanswered. For instance, what chemicals initiate and regulate the growth of buds and flowers? Plants make these organic chemicals for the same reason ductless glands in the human body make hormones: to direct the rate of growth of the plant.

You may make chemical analyses of plant tissue and come upon important discoveries. Recently ethylene gas was discovered in plants, where it acts as a plant hormone.

You might become a plant pathologist and study the diseases common to fruit trees, beet crops, tobacco and wheat. These diseases may be caused by bad weather, insects, germs or fungi! It may take you years of experimentation to isolate the cause. You might make "cultures" of the suspected organism, inoculate healthy plants with them and see what happens. If the same disease develops in the plants, you will study the habits and life history of this organism and devise ways to control it, or develop chemicals that will destroy it. You may be a plant physician. The fate of sick crops will depend on the correctness of your diagnosis and treatment.

For the most part, your method of overcoming diseases would be by selective breeding. You would seek to develop varieties immune to the disease. Do you see this field of cabbages? It was ravaged by "cabbage yellows," a disease peculiar to cabbages. But not all the heads are affected. Look at those healthy ones in the center of the stricken crop. They seem to be resistant to the disease. You might grow seeds from these healthy cabbages in your laboratory, plant and study the new shoots and cross-breed them with other varieties. You may

finally obtain a type of cabbage so immune to the disease that it will grow lustily even in diseased soil.

Problems like these are not easy. You might be working on them for as long as fifteen years – like William Saunders, for example. Together with his son, Dr. Charles Saunders, he was looking for a superior type of wheat, the staff of life, for much wheat is killed by fall frosts which endanger the nation's food supply. After years of disappointment, the two Saunders succeeded in developing a strain that ripens earlier, before the fall frosts appear, and so escapes the blight.

Experimenting in selective breeding, you may seek to grow new varieties that will be more productive per acre. It was due to the success of breeders in Cuba and Java that these two islands alone can produce at a profit all the sugar the world needs at a cost of only two cents a pound at the mills!

You might travel to Europe or Asia, perhaps, investigating different varieties of plants there and seek to transplant them in America, as biologist Mark Carleton did when he, too, sought a better grade of wheat, one that would not be killed by frost or disease. Carleton found the wheat he was looking for in Russia, on the steppes beyond the Urals. He took the seeds of these varieties back with him to America and had them planted all over the Middle West, from the Dakotas to Texas, even in desert-like regions. Would these strains survive the wheat plagues?

In 1904 came the crucial test: an epidemic of the dread "black stem rust" (fungi) swept over the wheat lands, crushing the life out of American varieties. Only Carleton's transplanted Russian wheat remained unharmed, thus saving the wheat crop for the American people. A great part of the nation's winter wheat yield in 1914 was his Russian variety.

Plant pathology is a new profession and now ranks with horticulture and soil science in importance. You might work in the Bureau of Plant Industry which employs a great num-

ber of pathologists. Your studies would be mostly of plant and fruit disease.

As plant pathologist, you should be well grounded in physics, chemistry and botany, including the physiology of plants, their anatomy and taxonomy (classification). You must study mycology (the study of fungi) because fungi are the main causes of diseases in plants. You must also be conversant with entomology (study of insects) and bacteriology.

Outstanding courses are given at leading universities, but you could study at your state agricultural college, and perform experiments in its agricultural station. After getting your degree, you might do graduate work on research problems.

If you worked for the Department of Agriculture in any of its divisions, you would start with a salary of from $1600 to $1800 a year. You would then be promoted to junior or district assistant with a salary of $2000 to $3000. The next higher position is state supervisor with a salary of $3000 to $5000. As regional chief, you would receive about $6000. The highest position in the department that you could attain would be that of department head. You would receive $8000 to $10,000.

As a soil scientist, you may specialize in soil chemistry or soil bacteriology. You might test hundreds of samples of soil sent to you from all parts of the country. You would find out by chemical analysis if the soil lacks iron or phosphorus, but you would also determine the amount of useful bacteria in it for some germs are necessary for good soil, and without them, plants refuse to grow.

Exactly what role do those bacteria play in the life of the soil? You might seek a solution of this problem through experiments. Maybe your findings would help the farmer raise better and more abundant crops from poor soil.

Every species of plant grows best in its own kind of soil.

You may conduct field experiments and check on "soil types" through laboratory tests, with the co-operation of farmers and foresters. Why is one type of soil better for oak trees, another for pasture grass, a third for cotton growing? You might do research to find out. You may experiment with chemicals and bacteria to change the capacity of the soil so that pasture land can grow cotton and vice versa.

As a soil scientist, you would have to be trained in geology as well as chemistry and physics. State agricultural colleges have facilities for teaching land reclamation work, soil surveys, soil physics, irrigation and soil fertility. Positions much sought after in this field of work are those of county agricultural agents and vocational agriculture instructors. They pay salaries ranging from $1800 to $5600.

You might become an entomologist and build your career on the study of insects. How important this work is to the farmer, is indicated by the fact that fully one-tenth of every crop is destroyed by these pests. At the same time, you will be helping the struggle against disease in man, for many insects are carriers of disease germs like malaria-bearing mosquitoes.

Every time you bite an apple and find it worm-eaten, you are up against a typical problem in entomology. How did the worm get into the apple? It is the larva of the codling moth which lays its eggs in apple blossoms, causing millions of dollars worth of damage to fruit crops every year. In spite of all the efforts of soil chemists, soil bacteriologists, plant pathologists and breeders, farmers' crops are in danger of destruction as long as they are exposed to the ravages of bugs and insects.

From the South Sea islands, some years ago, came clouds of insect pests called "leafhoppers." After many stops, they finally arrived in Hawaii where they swarmed by the millions upon the helpless sugar cane crops. The cane was stripped and withered. The cane growers faced ruin.

As an entomologist employed by the Department of Agriculture, you would be called upon to help solve problems of this kind. It might be quite a job, too. In this case, for example, entomologists experimented for years before they hit upon the solution. They introduced into Hawaii a variety of insect that lives on leafhoppers and destroys them. The problem was solved.

To be an entomologist, you would have to be educated in the life histories of insects, their hundreds of classifications, and their relationship to man, both harmful and beneficial. In addition to anatomy (body structure) and physiology (body function) of all classes of animals, you would have practical laboratory training in the collection of hundreds of insect specimens and learn methods of preserving and raising them.

You might study bacteriology and genetics (study of heredity). Your work would be varied and might take you to different parts of the world where you would investigate methods of insect control. You would probably be working for the State Division of Entomology which normally employs about 6000 experts in its continual warfare against this scourge of agriculture.

Your earnings would range from $1000 to $10,000 a year. If you worked for the United States Bureau of Entomology and Plant Quarantine, you would receive approximately $1020 as assistant field aid; $1440 as field aid; $2000 as field assistant; $2600 as assistant entomologist; $3200 as associate entomologist and $4600 as senior insect pathologist.

You might be a geneticist and specialize in the complicated study of heredity in plants or animals. In the botanical laboratory, you would "cross-pollinate" varieties of fruits, field crops, vegetables and try to develop new and better varieties as Luther Burbank did. You would seek better quality and

bigger crops as well as higher resistance to disease, insects, drought and frost.

You might experiment in breeding strains of cotton that could be gathered more easily by the mechanical picker. You would develop strains of fruits to which sulphur can be applied to control mildew without causing plant injury. Just recently such a strain was bred in cantaloupe. You might experiment with new, hybrid corn, like a recently grown variety which produces yields 30 per cent higher than the old kinds.

How would you proceed to breed new strains? One method is that of the physicist: the use of X-rays which change the offspring of plants in different ways by affecting the reproductive cells of the parents. Or you could use colchicine, the new chemical that has the same effect.

You might study weed control to save some of the $2,000,000,000 lost by American farmers every year because of unwanted plants in their fields. Weeds are stubborn things. Hoe them, plough them, cultivate them out, yet they return triumphantly. You may develop a chemical that would kill the weeds but not the cultivated plants. Such a chemical must be harmless to animals and to the soil itself! Progress has already been made in this direction. Will yours be a further contribution, a final solution?

Recognition of the importance of research science to agriculture received fresh impetus recently when the Sheffield Scientific School at Yale announced a new program of instruction in agricultural science to provide fundamental training.

Said Dr. Charles Seymour, president of Yale University: "The questions of better crop plants and domestic animals, of insect and fungus diseases, of soil fertility, of foods with the proper nutritive value and the whole question of food

preservation and processing are some of the problems which must be met, and to solve them will require a large number of men trained in the sciences fundamental to agriculture."

The new program will mark a departure in agricultural education, he added. It will resemble premedical training in being limited chiefly to the basic sciences like botany, zoology, chemistry, entomology, genetics. The object is to supply broad scientific training in the field, rather than practical farming knowledge. "Yale will not attempt to teach a man how to raise potatoes or run a dairy farm," said Dr. Seymour, "but rather how to use the basic sciences which he has mastered to solve such problems as developing vegetables with a higher vitamin content."

If you wish to be an agricultural scientist and do research work, this program, started in 1943, is ideally suited for training. You should write to the dean of the Sheffield Scientific School, New Haven, Connecticut, for further information.

The field of scientific agriculture is only one of the many fronts covered by biology. Yet, as you have seen, it is a vast field that challenges the best brains in many sciences. The need for soil and plant scientists after the war will increase greatly. One of the chief reasons for this is the increasing demand for higher standards of nutrition.

In the words of the National Planning Association: "The war itself is intensifying an understanding of the necessity for minimum dietary standards. We are increasingly aware that millions of our people have impaired health because of dietary deficiencies. The products of more than 20,000,000 additional acres would be needed, compared with 1936-1940, if the people of this country are to be better fed."

There is another reason why agricultural science will be increasingly important in the postwar era: the need for expanded food production due to a rise in population. It has been estimated that by 1960 there will be a probable increase

from about 130,000,000 as at present, to 150,000,000 people requiring an additional 40,000,000 acres of sown land to adequately support them. Add this to the rising need for farm products by industry, thanks to chemurgy, and you will have a dim idea of the tremendous demand for biologists and agricultural scientists in the postwar period.

Chapter VIII

BIOLOGY: CAREERS IN CONSERVATION

THERE is a roar of flame that spreads in sheets and tongues throughout the woods. In this inferno, the loftiest trees are no longer monarchs of the forest, but stacks of kindling wood. Hundreds of acres of timberland are in danger.

But the forest rangers are ready. With pick and shovel they advance and start digging in. Some rake debris and shovel dirt in the path of the fire; others beat the flames down with "spankers." In another sector, green clad rangers use the parallel method: they fall back in advance of the flames and quickly rake a deadline beyond which the fire cannot advance.

In some cases, the method of backfire is used: a liquid gas torch or flame-thrower starts a blaze moving in the opposite direction to that of the advancing wave of flame. Literally fighting fire with fire.

Conservation of natural resources is a division of biology that offers you fascinating out-of-door jobs and careers in the front line defense of your country's forests, wild animals, birds, land, soil, and water supply. These resources are in continual danger of being used up, wasted recklessly, or destroyed by fire, flood or other causes. Biologists come to the rescue and attack the problem on two fronts: prevention of destruction and renewal of resources by new plantings, introduction of new species, etc.

Consider the forests. They are one of the richest of your country's resources. Yet, in spite of firebreaks, lookout towers and other methods of fire detection, 50,000 fires make torches out of trees and destroy or damage an average of 12,000,000 acres every year. The direct loss to industry is a staggering

one, for trees are the source of paper pulp, textiles, dyes, turpentine and plastics as well as lumber. So great have the forest industries become that in 1939 they employed 1,250,000 people who made products valued at about $5,000,000,000.

But trees play a still more important role in retaining water, the life blood of the soil. In this way, they prevent parched regions and poor crops. In addition, they check floods and loss of soil from erosion, as their strong roots hold the earth back from wind and flood. They serve also as shelter and forage for wild animal life.

Employed as biologist by the United States Forest Service, you would thus be doing more than safeguarding trees for the lumber industry. You would be helping to protect the country's farms and food supply from flood, drought and dust storms.

What dangers threaten trees in addition to fires? One enemy that is ten times more destructive is the hordes of tree-destroying insects. Before the Forest Service was organized to combat them, whole areas of woodland were ruined by these pests. A major part of tree preservation is the control of gypsy moths, nut weevils, pine-bark beetles, white grubs and other six-legged destroyers endangering the forests. One method is to locate their breeding grounds and destroy them. Another is to plant trees scientifically so that species are mixed, as this prevents a concentrated attack by insects attached to certain species.

The biologist must also be on guard against tree diseases and remove all stricken trees, for epidemics break out among them just as they do among human beings. Tree surgeons must be ready to "operate" when necessary. Again, you might send tractors and spraying rigs into apple orchards to spray the leaves with chemicals that attack fungus diseases as well as insect pests. For spraying on a large scale, you may use airplanes which skim low over the tree tops and make

a powdery blitzkrieg with chemical dust. You might also receive regular reports from biologists in the plant quarantine service who examine specimens crossing the border, as tree diseases can be imported from other countries.

One important part of forest preservation is the replanting of trees that have been cut down or destroyed. Lumberjacks, toppling trees and cries of "timber" are thrilling things to see and hear in the movies. But ruthless cutting down of trees for lumber is one of the main reasons for the disappearance of our forests which once occupied almost half the land area of the United States. It has been estimated that 100,000,000 acres of trees have been hacked down by man himself.

It is not the cutting itself that destroys forests but the fact that this cutting is indiscriminate. As Robert M. Hallett wrote in the *Christian Science Monitor*, "By scientific cutting, it is possible to increase the annual new growth to a point where the yearly increment approximately balances the normal amount of timber used. Industry spokesmen stress that timber is a crop, like corn or wheat, and can be harvested and renewed. Actually, trees *need* to be cut to insure a future abundant supply of this natural resource, because trees grow old and rot, if they are not harvested to make way for a new crop. Wood researchers hold that continuation of their work promises increasing dividends in productive land use, waste utilization and employment."

You might direct the work of reforestation, rearing trees in government nurseries and having them planted in ploughed furrows. This involves consultations with seed specialists, for often the seed crop is poor and the problem of supplying good seeds for planting trees becomes a pressing one.

In preserving and multiplying trees, you would be helping to build up one of the mainstays of agriculture. This was dramatically shown in the Middle West in 1934. Choking in a strange dust, farmers gazed with red-rimmed eyes at

clouds of whirling acres of fertile soil blown skyward! Thousands of farms were destroyed in these dust storms with tons of thousands of head of livestock. Yet these storms were needless, for the chief cause was the absence of trees which serve as windbreaks, especially poplar trees, locusts and evergreens.

You might direct the planting of these trees along river banks. This prevents the washing away of rich top soil by floods as the roots hold the soil firmly in place. The Soil Conservation Service furnishes seeds to farmers for planting and advises them on improving the soil and increasing its fertility. You may work closely with biologists in the Conservation Service in such matters.

To qualify for a position with the United States Forest Service, which is a division of the federal government, you would have to have four years' college education. You could take courses in forestry in many universities, but for more thorough training, you would attend one of the twenty-seven accredited forestry schools.

If you are interested in forestry as a career, you should study botany, geology, zoology, general biology and chemistry in high school and junior college. Mathematics and public speaking are also recommended. For forestry proper, your courses should include dendrology (the natural history of trees), plant physiology and pathology (tree diseases), wood anatomy, entomology, the composition of soils and drafting.

After this basic training, you would take the following courses in your graduate work: silviculture (the care of trees), forest management, forest protection, forest products, lumbering, logging, milling, etc. You might do research work in the experimental forests administered by many of these schools.

After graduation, you might seek a civil service job as assistant forest ranger or junior forester. To qualify, you

must have had actual experience in forestry and be able to pass practical examinations. The highest position in a national forest is that of superviser: you would formulate forest policies and programs, to be carried out by logging engineers, range managers, etc.

Salaries vary. In the federal service, they range from $1200 to $2000 a year for forest guards, to $3800 or $4600 for either logging engineers or forest supervisors. Junior foresters, junior range conservationists and forest rangers receive $2000. Training in these jobs would give you a deeper insight into scientific research problems.

You might be employed in privately owned forests, for these constitute two-thirds of forest lands and are responsible for 97 per cent of all lumber products. The private companies employ over 1,000,000 people.

You might be an agrogeologist, another tough word, meaning a scientist who studies soils, their composition and physical structure, and be employed by the Soil Conservation Service. You may map out and classify soil areas and study their characteristics so as to determine whether they are better for cultivation, grazing or for forest land. Doing research and field work for the Department of Agriculture, you may teach farmers to avoid wasting and depleting their soil or growing the wrong kind of crops, for millions of dollars of waste could be avoided if farmers knew how to use the soil properly.

Teaching in agricultural colleges offers opportunity for research. You might investigate the chemical and biological qualities of the soil under different conditions of climate. Soils have life cycles just like animals. They are born, reach maturity, pass on to old age and decay. They can even be poisoned and made sick by improper nourishment. You might make valuable discoveries as a research physician of the soil.

Again, you might be a drain specialist. Poorly drained soil may mean crop failures even though it is rich and fertile. Or you might specialize in irrigation and reclamation of land. You would in any case study the effects of water on soil and plants. Your investigations may lead to discoveries of great value to the farmer, for water is important to vegetation: for every bushel of corn, the plants suck up almost ten tons of water through their roots.

Too little water is bad but too much water in the form of floods washes away the top soil and is another enemy that the soil conservationist fights with bulwarks of trees and dams. Every year, thousands of acres of earth are blown away by winds or carried off by floods. This leaves ridges and gullies of erosions and acres of clay in which nothing will grow but weeds.

Then consider how skimpy nature is in replacing this loss; soil comes from disintegrating rocks, but so slow is the process that it takes 4000 to 6000 years to produce only one foot of earth! Yet every year, 870,000,000 tons of earth are washed away, twice the amount of material removed in the building of the Panama Canal!

In this war against the waste of soil, biologists fight back with all the resources of scientific agriculture. Their weapons are the scientific planting of trees, proper vegetation, deep ploughing, and proper rotation of crops — for all this increases the capacity of the soil to absorb water.

Wind and water are the external enemies, but the soil can become barren from internal causes, from loss of the essential elements. You are still fighting the battle of conservation when you develop improved cultivation and better fertilizers for the soil; when you supply potash salts and phosphates, exactly as a doctor prescribes vitamins to a sick patient.

If you wanted to specialize in soil conservation, you would

apply for a position with the Soil Conservation Service (United States Department of Agriculture). To qualify, you would have to be a graduate of a four year course in an agricultural college. You would start as an assistant soil conservationist with a salary of $2600 a year. The highest position is that of senior soil conservationist with a salary of $4600. In addition to the prescribed educational requirements, you must have had practical experience in certain phases of agricultural work.

The fight to preserve forests and soil is only part of the war of preservation of our natural resources. You might choose another sector of the battle: the conservation of birds and wild animal life. In this field, you would be employed by the Biological Survey which maintains large preserves and refuges and controls the increase of animals injurious to man or plants like the coyote and wolf as well as rat, ground squirrel and jack rabbit. On the other hand, you might do work in increasing the supply of fur-bearing animals like the fox and the beaver, for these are useful to man.

You might tackle the problem of Alaskan reindeer. Why are they not more numerous and what can be done to increase their number? To answer these questions, you might make studies of the animals that prey upon them, like the wolf and coyote. Or you may investigate the diseases peculiar to reindeer and seek methods of prevention either by chemicals, change of diet or control of surroundings.

You might work for the survey in another field that is tremendously important to agriculture: preservation of bird life. For birds are the greatest mass murderers of insects in the world. Without them, your plants, trees, and food stocks would have been devoured years ago, so fast do insects breed and multiply.

Their destruction by birds is enormous. Consider the ordi-

nary house wren. It feeds its offspring insects, offering them beakfuls every two minutes and all day long! As ornithologist (bird scientist) and entomologist, you may study the various species of birds and the kind of insects they devour. You would discover that twenty-five species, for example, feed on the clover weevil, thirty-six species feed on the codling moth, which is so destructive to apples, and forty-six on the gypsy moth. It has been estimated that, every season, 4,000,000,000 birds prey on insects that damage the farmers' crops!

Birds are man's natural fighting planes in the war against insects. You have seen the harm these pests cause to forests. Even with the help of these winged destroyers, insects destroy one-tenth of the crops in addition to their tree destruction. Ceaselessly they spoil stored foods, bore tiny holes in timber, damage books and wooden implements and carry fatal diseases both to crops and to man. So important is the battle against these pests, it has been said that the future happiness and welfare of the human race depends largely upon the outcome of this struggle.

You might become an entomologist and specialize in the control of these insects. Not all insects are pests; the silkworm and bee, for example, are valuable to man and as entomologist, you would seek to protect and encourage their reproduction. Working in the Department of Agriculture, you might be employed by the Bureau of Entomology and Plant Quarantine. On the other hand, you may be one of the 6000 normally employed by the State Division of Entomology, which is a separate organization; or you might specialize in the collection, classification, and preservation of insects for museums. In the Bureau of Entomology, your salary would range anywhere from $1000 to $10,000 a year and you would probably start as field worker. As assistant field aid, you would receive $1020; as field aid, $1440; as field assistant,

$2000; as assistant entomologist, $2600; as associate entomologist, $3200; as senior insect pathologist, which is the highest position on the bureau, $4600.

In spite of their value, until comparatively recently, birds were slaughtered recklessly by sport lovers. Bird legislation has largely controlled this waste. Working for the Biological Survey, you might administer one of the eighty-three bird refuges and breeding grounds conducted by the survey. You may study diseases in birds and prepare tissues for microscopic investigation to search for evidence of these diseases. Studying the problems of the relation of bird to insect life, you may discover the kind of insects eaten by various birds by examining the contents of their stomachs in the laboratory. Where there is a shortage of bird food, you may see that it is provided or planted. Water fowl, for instance, eat wild millet, which is a small seeded cereal and forage grass. You might plant millet near streams where these birds are apt to congregate. The study of the migratory habits of water fowl is important for bird conservation. You may tag wild ducks with numbered bands having the words "Notify Washington." If captured anywhere in the country, their whereabouts would be revealed to the Fish and Wild Life Service (Department of Interior) and the information would disclose flying routes.

Demand for furs is growing every year but the number of fur-bearing animals is diminishing. Most fur farmers raise blue or silver foxes at present. How can these animals be made to reproduce more plentifully? How can disease be prevented and health promoted?

You might study these problems in fur-animal experimental stations conducted by the Biological Survey Bureau in the foothills of the Adirondacks and other regions. You would seek to improve the stock of foxes and other animals, by selective breeding, that is, breeding only those strains that

are the healthiest. You might investigate the parasites that live off these species and seek methods of controlling them.

The study of fish life is a major function of conservation. Until comparatively recently when the long arm of conservation reached out into the fisheries, this important food supply of the American people was sinking to the level of exhaustion. Waters once thick with halibut, shad, salmon, lobsters, and crabs showed less and less signs of life, as wasteful and unregulated fishing in all seasons and lack of scientific care of the animals began to show their effects.

Fish is important as a food because it contains vitamins, especially vitamin A, that are important for health. That is why the following warning by a scientist is a challenge to biologists as well as lawmakers: "All these animals show signs of depletion, some of which are so distinct as to be unmistakable." And that is why the federal government maintains 99 fish hatcheries, which produce between 6,000,000,000 and 7,000,000,000 fish each year to stock American waters.

Working for the Bureau of Fisheries, you may fight this depletion by artificially impregnating the eggs laid by the female so as to increase the number of offspring. You might introduce new species in waters that are not sufficiently productive. It is important, also, to protect breeding grounds and see that lakes and streams are not polluted, as fish life can be destroyed by these poisons. You might be employed by the state instead of the federal government as states maintain their own fisheries and experimental stations.

Proper nourishment and care of fish is an important factor in preservation. Working for the Fish and Wild Life Service, you may play host to thousands of trout by visiting them regularly in their hatcheries at the dinner hour with buckets of food. Or you might fly by plane to a distant lake and set cans of baby fish, perhaps small-mouth bass fingerlings, into the water near the shore. This assures careful adjustment of

temperature and protects them until they are strong enough to be released, swelling the bass supply in the lake.

If you wish to specialize in this branch of conservation, you will have to be a college graduate with a bachelor's degree and have majored in a branch of biology. You would then be qualified for the position of junior aquatic biologist. Your salary would start at $2000.

Your qualifications would have to be higher for the job of assistant aquatic biologist. You would need two years, in addition, of practical experience. For one of these two years, you may substitute a year of graduate work in biology instead. Your salary would then start at $2600.

With three additional years of practical experience, or a doctor's degree instead, you would qualify for associate aquatic biologist. Entrance salary is $3200. The next higher position is that of full aquatic biologist. Three years of professional experience after graduation are required. In this capacity, you would conduct specialized, independent investigations as well as do administrative work. Entrance salary is $3800.

These positions are all on a civil service basis. The highest positions in the service are those of senior, principal, head and chief aquatic biologists. They are usually filled by promotion from lower grades.

Hard hit by destruction of birds, small fur-bearing animals and fish, our natural resources have been further crippled by wholesale destruction of big game life. Just as mass production fishing off the New England coast has decimated an entire species of shad, so has wholesale hunting killed off the shaggy buffalo that used to roam the Western plains until today it is almost extinct.

For this reason, the preservation of big game life is an important function of the Biological Survey. You might work on the National Bison Range in Montana, and study the rear-

ing and more fruitful reproduction of mountain sheep. These animals are relatively scarce, but thanks to the survey, they are growing in population. Thus, 12 sheep corraled in 1922 increased in eight years to 100. Or you might work in the reindeer experimental station near Fairbanks, Alaska, and conduct cross-breeding experiments to improve the stock of this animal so important to Alaskan industry.

The preservation of animal life includes the curbing and destruction of predatory animals. Employed by the Fish and Wildlife Service, you might trap coyotes, bobcats, wolves, bears and mountain lions. In 1943, a total of 115,287 of these animals were destroyed in operations carried on in twenty-nine states in co-operation with the federal government. Of the various methods used, trapping accounted for 78,444 of the total.

The science of conservation of our natural resources may well be called the Science of Out-of-Doors. It is a "must" occupation for you if you love science and the woods and sunshine at the same time! It offers opportunities in a score of fields embracing animal and plant life, in which you would be doing any one of a variety of fascinating things, from rearing plants for study to building cages for animals. You might ride for days on horseback, doing field work. You may also spend days in an office or laboratory, poring over charts, statistics and test tubes.

One day you may hoist beavers into trucks, to remove them to another area of the forest where the dams they build so ingeniously will help to hold flooding spring waters in check. Then again you might be setting insect traps to catch the ravaging Japanese beetle. You might be out on a bay in a small boat, setting a "purse seine" for a big catch of salmon. Or working again in the laboratory, you might be making microscopic studies to try to improve the quality of furs of wild animals raised in captivity, or experimenting in insect

control and studying the effect of a drop of nicotine applied to the heart of a cockroach!

Whether you hurry to fight a forest fire or study the ravages of a plant disease or analyze a sample of top soil or build a fish hatchery or instruct farmers in the proper planting of trees or proceed against violators of hunting or fishing regulations, you are a soldier in the army of conservation. It is a mighty, complex army that never sleeps. Daytime and night time it is on the alert, guarding America's richest heritage – the richest in the world – her vast, natural resources.

Chapter IX

BIOLOGY: OUTWITTING THE GERM

> Take a great beetle and cut off his head and wings; boil him, put him in oil and lay him out, then cook his head and wings. Put them in snake fat, boil and let the patient drink the mixture.

SUCH was the practice of medicine in some of the American colonies a few centuries ago. Disease was a devil inside of you that could be exorcised only if your body were tortured on the rack. When a plague broke out, innocent people were burnt alive at the stake, charged with being the cause.

What a contrast today! There are hospitals and laboratories and microscopes. There are X-ray machines and fluoroscopes, food experts and blood analysts. Science has taken the place of superstition in the treatment of disease. Fear has given way to knowledge. As this knowledge grew, the scientific training required of medical doctors grew in proportion. Today, this training is probably the hardest and most exhaustive of all professions.

The medical student dissecting bodies in the laboratory is probably unaware of his good fortune. In the sixteenth century, Vesalius, who made important discoveries in anatomy, was not permitted to engage in this devilish work; he had to steal to the gallows at night and remove the corpses secretly for his dissections. Medicine is a young science; it was not until 1628 that Harvey proved experimentally how the blood circulates. And it is less than a hundred years ago that a stubborn chemist named Louis Pasteur braved the jeers of eminent physicians by advancing his germ theory of disease.

Medical science is a fast-growing offshoot of biology. To most people, it means John Smith, M.D. But behind the doctor are pathologists, chemists, bacteriologists, anatomists, food analysts, physicists, physiologists, sanitation engineers, pharmacologists.

You might become a medical scientist with an M.D. degree and work for the federal government. You would be a soldier in an army that is fighting a war twenty-four hours a day and seven days a week – the United States Public Health Service. As military armies are organized into platoons, regiments, corps, battalions, and divisions, so this army of disease-fighters is organized into health departments with auxiliary detachments of clinics, hospitals, and laboratories. As in the army, there are corps of specialists to spy on the enemy, ferret him out, engage and destroy him. There are not only physicians but inspectors, research men, teachers, statisticians and zoologists.

Appropriately enough, the head of the service is called a surgeon general. There are eight main divisions with an assistant surgeon general in charge of each. No matter which division you joined, your work would be a part of the common struggle having two objectives: to prevent disease and to treat it successfully when it breaks out.

You might be employed by the Division of Scientific Research and experiment in the effects of drugs and chemicals on diseased animals. This is one of the nine divisions of the National Institute of Health, the research branch of the service. New chemical applications discovered in recent years have advanced the treatment of some diseases to an amazing extent. You are already familiar with the new words sulfa drugs, penicillin, synthetic vitamins – words which have made the front pages of newspapers in startling reports of cures.

You might carry on this work, seeking to discover more effective drugs, better methods of prevention and treatment



A geologist inspects specimen of benitoite from a quicksilver mine to determine the crystal pattern.

(U. S. CIVIL SERVICE COMMISSION)



These two young meteorologists in the U. S. Weather Bureau's Extended Forecast and Research Division are analyzing upper air charts in preparing a weather forecast.

(U. S. CIVIL SERVICE COMMISSION)



Dr. Waldo Semon, director of pioneering research for the B. F. Goodrich Company.

(B. F. GOODRICH COMPANY)



Dr. C. H. Bachman uses electron microscope in electronics laboratory of General Electric's Schenectady works.
(GENERAL ELECTRIC)



[illegible] *f the Insulation Department, Westinghouse* [illegible] *h Laboratories, demonstrates strength of a new plastic by* [illegible] *hand of material to a stress twice its own weight.*



Dr. E. B. Ashcraft, microchemist, makes permanent records of how things look under a high-power microscope with this combination of microscope and camera at Westinghouse Research Laboratories.

(WESTINGHOUSE)



Dr. E. B. Ashcraft, Westinghouse microchemist, with "vest-pocket" chemical tools, discovered more than 100 causes of spots on metals, and thus improved operation of electrical apparatus from vacuum tubes to 1,000-ton generators.

(WESTINGHOUSE)

You may study sulfanilamide, the magic drug that attacks thirty different diseases, has cut the death rate from pneumonia almost two-thirds in five years, and reduced by 35 per cent the death rate from appendicitis. You might investigate its effects on other diseases like, gonorrhea, erysipelas, scarlet fever, tonsillitis.

How does sulfanilamide operate? It does not destroy the disease germs directly. Instead, it builds a wall around them, thus shutting off their food supplies and starving them out. The germs, unable to multiply, are easily overcome by the phagocytes, your body's defensive army of white blood corpuscles. However, several problems still remain to be solved. You might make microscopic studies of the war going on in diseased tissue between germs and phagocytes much as a general views a battle through his telescope. You may find the answers to these questions.

You might develop derivatives from the sulfa drug. More than 1,000 of these are being studied today by biologists. In particular, you might specialize in intestinal infections, like dysentery, and seek a sulfa derivative that is especially effective against these diseases — like phthalyl-sulfathiazole, discovered as recently as May, 1943.

Or you might work on rheumatic fever in children, a terrible disease that causes seven times more deaths than infantile paralysis. The sulfa drugs cut down the recurrence of rheumatic fever. You might develop a vaccine that will prevent it altogether!

These drugs are effective weapons in the war against disease but like all weapons, they have their limitations. They make the patient suffer from dizziness and nausea. They fail ogether in many cases. Why? To find out, you might study e progress of pneumonia, say, in two groups of patients: group would be treated with the sulfa drugs, the other ed the "control" group) would not. In this way, you

might be able to make comparisons and check on the effects of the drug at every stage of the disease.

You may study another wonder drug: penicillin, a yellow extract from a green mold like the kind you sometimes see on bread. Discovered in 1929 by an English bacteriologist, it is "far superior to any of the sulfanilamides," to quote the *Journal of the American Medical Association*. It has a more powerful effect on the dread bone disease called osteomyelitis and the pus germ (staphylococcus). It does not have the harmful effects of the sulfa drugs.

The extraction of penicillin is a difficult and costly process. Nevertheless, it has proved so effective that the War Production Board during the war ordered nine chemical firms to build a $3,000,000 plant to manufacture it. Can penicillin, so difficult to obtain, be made artificially from coal tar compounds? Chemists are working on this possibility which would make the drug easily available for every doctor in the country.

Working with chemists, you, too, might experiment with the green mold, and seek to develop other drugs from its rubbery substance. Recently, a new type of penicillin, called penicillin B, was discovered by research scientists at St. Louis University. It belongs to a chemical group known as the acridines. Some of these acridines are a hundred times more powerful in destroying bacteria than the sulfa drugs.

The acridines attack disease germs by depriving them of oxygen, thus asphyxiating them! Some of these drugs, on the contrary, overcome the germs with too much oxygen, in the form of hydrogen peroxide — the chemical that you use when you cut your finger. This excess oxygen literally burns the bacteria alive.

You might experiment with other new found drugs like dicoumarin, which has already saved many lives by prevent-

ing clots inside blood vessels, and gramicidin, which has cleared up sinus infections in forty-eight hours.

Chemicals and drugs are only one method of prevention and cure of diseases. Vitamins and hormones are also important. As research biologist in one of the divisions of the National Institute of Health, you could choose your enemy and your weapon.

You might concentrate on one of the three murderers of the American people: heart disease, cancer and pneumonia. You might explore the unknown cause of the common cold, grapple with the problem of the prevention of measles, which still flourishes (in 1934, it broke a twenty-one year old record in victims), experiment with better chemicals than insulin, which requires frequent painful injections in the treatment of diabetes.

You may experiment with the replacement of dead or damaged organs of the body. As a rule, transplanted organs die in a short time, but there are exceptions, notably certain ductless glands. Recently, a Soviet scientist replaced the heart of a frog with that of another frog. The transplanted heart functioned normally and the frog lived over one hundred days and showed no ill effects.

You might repair severed nerves and prevent paralysis of muscles by taking a piece of nerve from a dead person and gluing it into place in the gap of the living nerve. Along this "trellis," new fibers of the severed nerve often grow!

You may cut out the diseased opaque cornea from an affected eyeball and graft onto it a piece of transparent, healthy cornea taken from the eyeball of a cadaver. Eyeball banks have been established for this purpose, just like blood banks. In this way, you would be literally giving sight to the blind in many cases.

You might specialize in anesthesia, a boon to suffering man-

kind that has its own dramatic history. The war has resulted in startling developments in this field with the discovery of new agents, like the gas called cyclopropane and the magical drug, pentothal, used in probably 75 per cent of all cases requiring anesthesia on the battlefield.

You might specialize in food chemistry and nutrition, and study vitamins, which were unknown before 1906. You may investigate diseases like beriberi and pellagra, caused by lack of vitamin B in food. You might experiment with biotin, one of the B vitamins. This is so rare that the world's entire supply amounts to only one-tenth of an ounce. It takes 550 pounds of dried yolk of duck's eggs to extract an infinitesimal amount, and for one ounce, $4,000,000 was paid in 1936.

What is this vitamin good for? To find out experimentally you would eliminate biotin from the food of selected plants and animals. Biologists report that in this case they wither and die; also that animals without biotin in their food succumb to cancer and tuberculosis. Is biotin a clue to these diseases, as some research men think? Perhaps you may throw light on this problem through your own experiments.

Chemists can now create fourteen different vitamins in synthetic form. You might discover new varieties or develop new methods of synthesizing the elements that compose them. On the other hand, you may conduct nutrition experiments on adolescents and study the effects of bacteria in the intestines. Research men have discovered that these bacteria produce a vitamin B (thiamin), which is necessary to protect them from beriberi. These are health-producing bacteria and must not be confused with disease germs.

In the laboratory you may feed rats food deficient in certain vitamins and discover new facts. It has been found, for instance, that rats will thrive without B vitamins but fall sick from vitamin-deficiency if sulfa drugs are injected! This

shows that these drugs block the action of the bacteria in the intestines that create these vitamins.

Working for the Public Health Service, you would have a far greater opportunity and more facilities to conduct medical research than if you were in private practice. As Dr. Adrian G. Gould says in *Careers in Public Health* (Science Research Associates): "Much of the research in the field of medicine which has developed preventive vaccines, toxoids and curative serums and discovered the causes of disease, has been carried on under the sponsorship of public health agencies. Physicians in private practice often have neither the time nor the money to do such research but public health organizations include it as a regular part of their program."

This is particularly true if you wanted to study epidemics and become an epidemiologist. You would then work in the Division of Domestic Quarantines which is linked with the health services in all states of the Union. This department furnishes consultant service in public health engineering, nursing, education, industrial hygiene, mental hygiene, malaria control, milk sanitation, nutrition, laboratory aid – for all these specialties are important in the war against epidemics.

Suppose a typhoid fever plague broke out in a large city. You might be called in to track down the cause. First, you would analyze the data and statistics collected by the city health department. A study of the data would help to rule out many possibilities. Suppose, for example, most of the victims of the disease drank pasteurized milk and suppose there were only one large distributor in the city.

You might have all the employees in the pasteurizing plant examined for typhus. This is what actually happened in one case. None of the employees had the germ. The water supply and vegetable markets were then investigated, but the results were zero.

What would you do in a case like this? Perhaps you would reason like the state epidemiologist who finally solved the mystery. He concluded that, as no germs had been discovered up to the time of bottling the milk, the infection must have been introduced at some time either during or after the bottling.

He visited the bottling plant again. All workers there had been examined and were declared germ-free.But investigators noticed that one machine used to cap the bottle was not working properly. Whenever it failed, the operator capped the bottles by hand. He was re-examined, this time more carefully. Result: he was discovered to be carrying the dread germ!

As epidemiologist, you would have to be familiar with the workings of the department of sanitation. This is a huge, complex organization. It maintains safe and adequate water supply, proper sewage for waste, proper disposal of garbage and refuse, housing regulations to insure health and sanitation, control of breeding places of disease like malaria-breeding swamps.

You would consult with the technicians and experts in the Public Health Service — house inspectors, food inspectors, water inspectors, civil engineers, forest rangers, milk experts, specialists in canning of foods, transportation, etc., for all of their fields are involved in the spread of epidemics across the country.

In another division, you might do research work for the Department of Industrial Hygiene. You might concentrate on occupational diseases like silicosis, a lung disease acquired in the quarries. There are sixty technical workers on the staff. You would visit factories and mines, study the factors that cause injuries and disease and investigate ways of eliminating them.

If you are interested in mental ills, you might work in

the Division of Mental Hygiene, which grapples with the problems of drug addicts and the feeble-minded. You might investigate the new insulin "shock" treatment of mental disease, called by some doctors the first scientific approach to the treatment of insanity. The subject is important today as from 30 to 40 per cent of all war casualties are expected to be mental cases. Perhaps you may make discoveries that will be a boon to the 4,000,000 feeble-minded in the United States.

You might be employed by the Public Health Service at its National Cancer Institute at Bethesda, Maryland, greatest cancer laboratory in the world. Cancer is one of the greatest scourges of humanity. Every year, 2,000,000 people die from it throughout the world. Every three and a half minutes in the United States, a human life ends, struck down by this disease. What causes cancer and how can it be prevented?

Here at the laboratories of the institute, you may join the collective search to find the answer. It is possible to grow cancer cells in mice, rats and guinea pigs. You might experiment with chemicals that produce the disease so that you can study its development. Over two hundred of these chemicals have already been discovered, one so powerful that only one twenty-five millionth of an ounce can produce cancer in mice! You might expose mice to ultra-violet lamps and produce skin cancer in that way.

Is cancer of the lungs caused by sooty air in big cities? To investigate this problem, you may set up apparatus in the cities to collect the soot. Back in the laboratory, you would extract coal tars and with these tars try to produce tumors in mice. What is the answer? There is a certain amount of evidence, but scientists aren't talking – yet! You might discover evidence that high smoke content is the cause in many cases, where there is a predisposition to the disease.

Biologists can grow healthy tissue in a laboratory flask. Then they add a cancer-producing chemical, like a coal tar

extract. Watching through a microscope, they witness the normal cells clumping together in a disorderly mass. You would withdraw some of the tissue and implant it under the skin of a mouse. Maybe nothing happens, or maybe within two weeks, a hard mass begins to form under the skin. Yes, these are cancer cells that you have artificially produced in the flask! The new method was developed in the institute for the first time in 1943.

You might seek by experiment to develop a positive test for cancer that would indicate the presence of the tumors. This is important, for people may have the disease without knowing it, since it rarely causes pain in its early stages.

There are at present but three effective weapons against this disease: radiation with X-rays, radium, and the surgeon's knife. You might investigate other methods, like the newly developed administration of sex hormones. You may experiment with mice that are predisposed to cancer of the breast, say, and see if you can prevent it by injections or other methods.

What qualifications would you need for a scientific career in public health? In the first place, of course, to be a health officer, you will need an M.D. degree. Again, while some medical schools theoretically require only two or three years of premedical education, competition was so keen before the war that only students who had graduated from college with a degree were accepted by recognized schools of medicine.

Medical training is exceptionally long and thorough. For this reason, it would be advisable for you to take as much chemistry and biology in high school as possible, but physics and mathematics should not be neglected, as they are vital to research.

After you have obtained your medical degree, you must take at least one year of graduate instruction in a university leading to a degree in public health. In small communities,

you are allowed to substitute three months of supervised field experience in a health department. You will then be ready for the civil service examinations.

There are fifteen optional branches open to you, including rural practice, the Indian Service, employment in the Panama Canal Zone, duty with the Veterans Administration, work with the Food and Drug Administration and the care of children in the Children's Bureau. You would have your choice of work in government hospitals, general practice, school health work, quarantine work, immigration inspection, research, tuberculosis diagnosis and control, psychiatric care, surgery, administration of clinics in hospitals and sanitariums, control of the labeling of foods and drugs, and furtherance of child hygiene. Specialized practical work is sometimes an excellent preliminary to research. For example, if you work in the Food and Drug Administration of the Federal Security Agency, you may test and analyze foods, drugs and cosmetics to determine whether the claims and data on the labels are true or not. For research in nutrition or medicine, this might be a wise course to follow, as you could familiarize yourself with concrete problems of public health.

The importance of this work is shown by the fact that in 1943, over 56,000 samples were inspected. Furthermore, the products of more than 3,000 distributors of adulterated or dangerous goods were exposed and confiscated. Employed as a scientist in the Washington laboratories, you would be working among bacteriologists, pharmacologists, analytical chemists and biologists, with the finest scientific apparatus at your disposal – equipment estimated to cost $1,500,000.

Salaries for commissioned personnel of the United States Public Health Service increase with rank and are similar to those received by those commissioned in the army and navy. In general, the base pay ranges from $2,000 to $8,000 a year with additional allowances for subsistence dependents. As

associate medical officer, you would receive $3,200 a year; as medical officer, $3,800 a year and as senior medical officer, $4,600.

In addition to the federal service, there are state and county public health departments. As a state health officer, you would receive from $4,000 to $6,000 a year. As county health officer, your salary would range anywhere from $3,600 to $5,800, some receiving considerably more.

If you specialized in public health engineering, your education and training would have to be in the fields of sanitary, civil, or chemical engineering. You would do graduate work in vital statistics (that is, statistics dealing with births and deaths of the population as a whole), epidemics and their prevention by control of water, sewage, insects, etc.

Your salary as sanitary engineer on the staff of a state health department would be from $3,000 to $6,500. This would be excellent preparatory training if you intended doing research in epidemics toward becoming an epidemiologist.

If you became a health officer in a city department, your salary would range anywhere from $3,000 up to $15,000, depending on the location.

What are the hours of work in public health? There are no definite hours, theoretically, for an epidemic might break out that may keep you on call twenty-four hours a day! But actually, your hours would be about the same as those of most business people, with the exception that you would probably have to work on legal holidays. You would not be paid for overtime work but this does not occur very often.

On the other hand, you would receive the benefits and security of a civil service position, with from two to four weeks' vacation with pay and sick leave up to two weeks' a year, also with pay.

A certain amount of danger to your health is unavoidable

in this work. If you do field work, you may be called out in all sorts of weather to visit sick people. As bacteriologist, assistant physician or epidemiologist, you may be placed in contact with infectious diseases. In addition, while doing research work in the laboratory, you take the risk of acquiring diseases from handling virulent germs.

To the young man or woman interested in a scientific career in public health, however, these hazards will not be serious obstacles. They are insignificant compared to the satisfaction that comes from performing a vital public service, from safeguarding the lives of the people, from building up the nation's health, from adding to present day knowledge of the causes of diseases, their treatment and prevention.

What is the outlook for employment in this field? The answer is: unusually bright – and for at least three reasons: (1) Even before the war there was a dearth of public health workers all over the country, especially in the rural areas. Half the population in the United States lives in small towns and country places, yet only 60 per cent of the counties had full time health services. (2) The war has taken a heavy toll of these workers, including health officers. There will be a crying need for more doctors, nurses and sanitary engineers when peace returns, according to medical health officers. Medical schools are planning now for the difficult period of adjustment in the postwar period. (3) The increasing trend toward socialized medicine both in England and in this country points to expanded government health services after the war. This means even more nurses, sanitary engineers, bacteriologists, statisticians, educators and many more research men and women in the laboratories of all nine divisions of the Service's National Institute of Health.

Reports that about one-third of the men in the United States had to be rejected from service in the armed forces because of physical disabilities and almost the same propor-

tion of women, reveal a serious health situation that has spurred demand for education, prevention and treatment of disease on a larger scale than ever before.

In July, 1944, Dr. Thomas Parran, Surgeon General of the Public Health Service, presented in detail a program that was backed by the Service. It provides for the establishment of one or more base hospitals in every state, numerous district hospitals with modern equipment and small health centers in remote communities for medical advice and assistance in regions which hitherto have lacked them. The program is a comprehensive one and would cost the government about $2,000,000,000.

"The physician of today will go where there are hospitals," said Dr. Parran. "There is need for a newer type of family physician who has at his command the complicated instruments and specialized knowledge to prevent and detect disease and remove its causes. In the future, medical men will grow more and more accustomed to working as a team and not as individual competitors."

The program calls for a greatly expanded Public Health Service, as every community center, which would be the headquarters of a resident nurse, would also contain offices of the service. Dr. Parran stressed the need for more education. He said that medical science was expanding and evolving so rapidly that even medical students who were just graduated were in need of instruction. This instruction, according to the program, would be furnished at the base hospitals.

There can be only one conclusion: the combination of a greatly enlarged public health service after the war, opening up hundreds of new jobs and careers that did not exist before, and the giant strides forward taken by medical research during the past ten years, all means tremendously expanding opportunities in the field of public health. The money reward is not large but no career offers richer prizes in inner satisfac-

tion. To many, it will be the most exciting and fascinating of all fields of biology.

The United States Public Health Service is a mighty fighting army. Its war will still be waging when World War II is a thing of the past. Indeed, at that time, it will need more recruits than ever.

Want to join up? Have you got what it takes? Have you the price of admission?

Chapter X

GEOLOGY: DOWN TO EARTH FOR A JOB

WHAT happened 2,000,000,000 years ago? Most people would not be able to answer this question, although they may remember many important events in history. Yet this was undeniably the top event of them all.

For about that time, geologists believe, a star crashed by accident into the sun, and tore off a chunk that went spinning off into space, cooled, and hardened and became the earth on which you live, struggle and wonder what career to adopt for your brief life span!

Thus was born the stuff of geology, the science of the composition and development of the earth, from its hot, inner core to its outer surfaces of mountains, plains and oceans. For a long time, geologists were classed with archeologists, who dug up ancient ruins and were more interested in scholarly research than in practical applications. Geologists could answer fascinating questions, like why don't mountains sink into the earth of their own weight? Or, what causes ocean tides? But their science was felt to be the exclusive concern of impractical, academical professors, having no vital connection with the workaday world.

Today, all that is changed. Geologists are in heavy demand in mining and industry. All digging and building of any sort requires a geological knowledge of the various formations and rock strata. Geologists are consulted in the selection of sites and the building of the foundation. But they are consulted also in the selection of building material itself, especially for dams, reservoirs, bridges and skyscrapers.

They are experts, not only of the earth but of the oil and mineral and metal deposits buried within it. You might have

neither automobile nor gas to run it if it were not for the geologist who located the oil and metal from which your car was made, and helped to bring them to the surface. Coal and raw materials needed by modern industry, like sulphur, graphite, nitrates and marble, would likewise be lacking to a large extent if it were not for the geologist's knowledge of rock structures. The old time prospectors with their sombreros, picks and pack burros could hardly supply the demands of mass production today with their hit-or-miss methods of prospecting. The location of ore bodies is an important part of the geologist's work, and highlights the industrial importance of geology.

In addition, geologists help to protect man against the worst catastrophes of nature: floods, earthquakes and volcanic discharges. They can gauge the probabilities of earthquakes in any region by their knowledge of the internal structure of the earth. Similarly, in volcanic regions, they can determine the probability of fresh eruptions.

Every time you are thirsty and turn to the kitchen sink for water, you are illustrating another practical application of geology. The collection and distribution of drinking water was made available by engineers working with geologists in the construction of dams, reservoirs and water pipes. The location of water is a particularly acute problem in arid regions.

In 1942, for example, the Geological Survey made reports on investigations for ground water at some 900 places for the army and navy and war industries. The finding of water was especially important in North Africa, and ten geologists were commissioned as officers and detailed to locate water sources.

There are many branches of specialization in the field of geology. Take the field of engineering geology. If you specialize in this direction, you might find yourself the

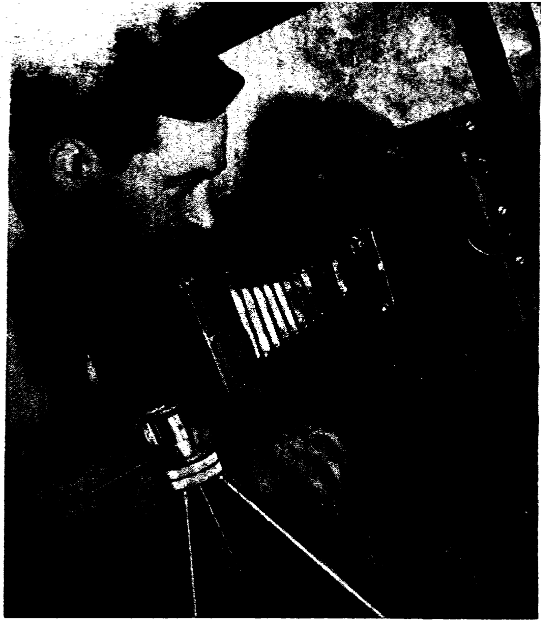
planner behind heavy construction work. You may determine the best available sites for the building of bridges or skyscrapers. The construction of such majestic creations as the George Washington Bridge or the Boulder Dam may be partly your responsibility.

One of the most fascinating histories in the world is the history of the earth itself. You might specialize in this branch, called paleontology or historical geology. This is the science of deciphering the past from the only records available, the rocks themselves. It is thanks to paleontologists that this history has been revealed, a fascinating story of shifting climate and land surfaces; of changing vegetation through the centuries; of continents and mountains being worn to dust by thousands of years of attrition, and of the ice ages when ice sheets covered large areas of the globe.

Again you might become an economic geologist and assist in the discovery of mineral deposits. By studies of the rocks and their formations, you would figure out the relationships of the beds and gather data on which to estimate the probable amount of reserve deposits. This is practical work; you would analyze the quality of the mineral, also its nearness to railroads and waterways, since you might be consulted also regarding cost of mining and transportation charges to avoid unprofitable mining.

You might work for a mining company and direct mining operations. If so, you would descend into the mine yourself and study the underground workings, in addition to analyzing and measuring the surface formations. You may make laboratory tests and also geologic maps of the region mined. This would control the mining operations and serve as a guide for further explorations in the territory.

Engaged in federal or state surveys, you might be mapping out your country's coal resources. You may study the r formations to determine where the deposits are, how exte



(WESTINGHOUSE)

Samuel Gilman, Westinghouse research engineer, with camera he uses to take "portraits" of water droplets so they can be measured accurately.



(WESTINGHOUSE)

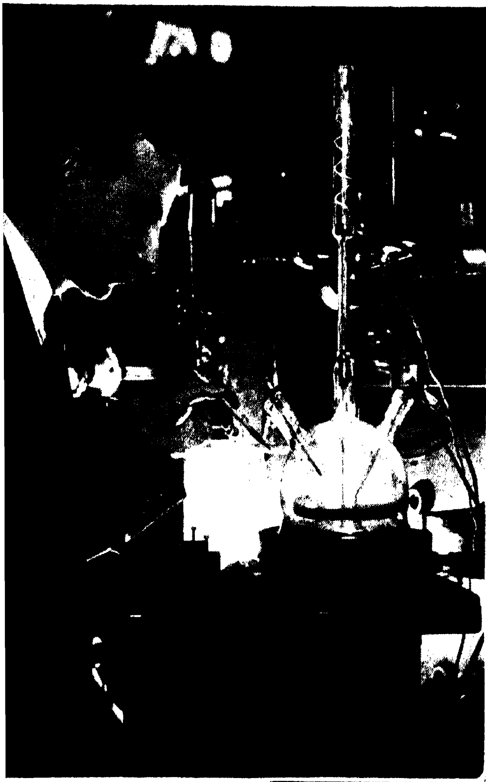
Dr. J. A. Whipple, Westinghouse research physicist, connects vacuum tube of "atom sorter," or mass spectrometer, a device he developed to sort atoms by weight and thus help control the refining of gasoline.



J. R. Gier, Westinghouse metallurgist, at work with one of experimental electric furnaces used in development of "Endogas" atmosphere, new mixture used to blanket high grade steel parts against heat burn during hardening process. (WESTINGHOUSE)

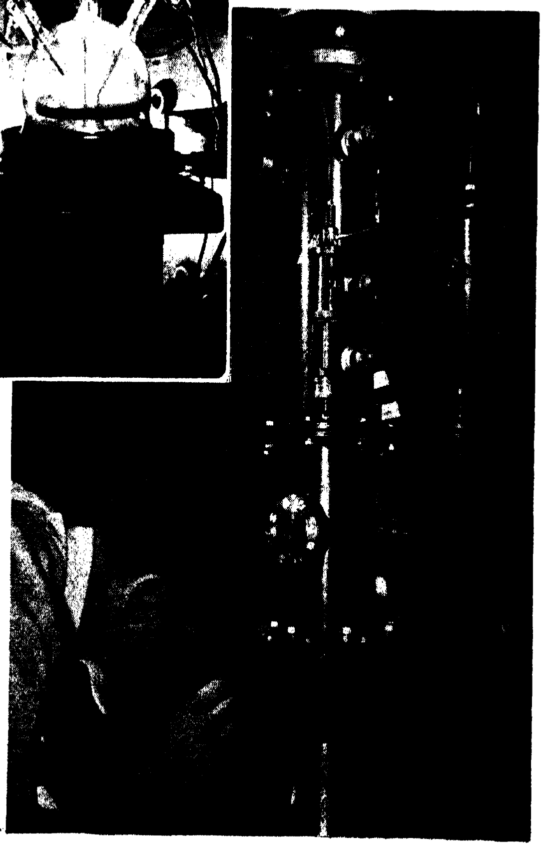


Julia Senko, an industrial hygiene chemist, test
house shops to make sure it contains no healt
solvents. (WESTINGHOUSE)



Dr. Joseph Slepien, who with Leon R. Ludwig, both Westinghouse research engineers, developed "ignitron" control, watches laboratory test of device, which uses tiny current applied to pencil igniter to control currents million times greater in an electrical arc.

(WESTINGHOUSE)

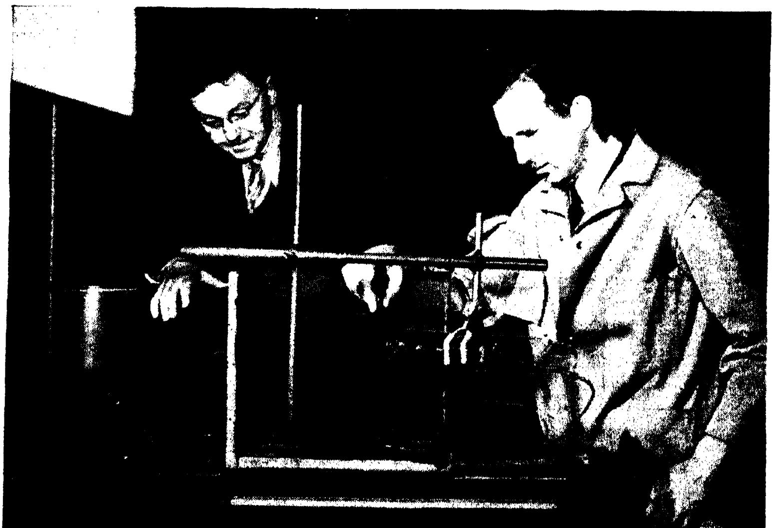


Earl A. Gulbransen ...ng sights of his ...ctronic diffraction cam... , a device that shoots ... electronic ... cond.

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Dr. Miklos Hetenyi, Westinghouse engineer, with polarized light camera he uses to determine stresses inside nuts and bolts.
(WESTINGHOUSE)



An electronic instrument to measure nation's "sunfall" for first time is tested at Westinghouse lamp research laboratories in Bloomfield, N. J. Dr. H. C. Rentschler, inventor, is at left. (WESTINGHOUSE)

sive and which beds are best for coking and for steam production.

In general, no matter what branch of geology you enter, you will find your work divided into field work and laboratory work. In the field, geologists collect samples of rock and soil, study rock layers, map territory indicating the various types of rocks and breaks in the layers. Working in the laboratory, they make maps of the region and chart the various geologic formations. They make chemical analyses of the rocks collected and test them for age. This reveals the past geologic history of the region.

Private industry offers the best job opportunities in geology. The majority of geologists in industry are with oil or mining companies. The salary for a typical job with an oil corporation starts at about $140 a month, with field expenses paid. This is an important item, since considerable traveling is involved. Usually, the geologist receives regular increases in pay until he is earning, within a few years, about $300 a month. The position of resident geologist, which represents the next promotional step, pays about $500 a month. This position is in the executive field and generally embraces a staff of assistants who are directly responsible to the resident geologist. The top jobs within the reach of the resident geologists who are really successful are assistant chief geologist and chief geologist. The salaries vary according to the size of the industry and the scope of the position but the maximum yearly salary is about $15,000 a year. A number of geologists who have proved themselves in industry, establish themselves independently as consultants.

In recent years, the search for new supplies of petroleum has become increasingly the work of the geologist. It may give you an idea of how recent this field of work is when you consider that only eighty years ago, all the oil used in the United States came from the blubber of whales. The

maximum supply obtainable from this source was 1,000,000 barrels a year. In 1938 alone, American industry used 21,248,000 barrels!

The importance of petroleum to industry is shown by the fact that it yields more than three hundred essential products. Oil is necessary for heat, power, transportation, and manufacturing. The industry has become so gigantic in scope that it employs 1,000,000 workers, pays them $1,500,000,000 a year and contributes more than $4,000,000,000 every year to the national economy, in normal times.

It is because of this demand for petroleum that the danger of exhaustion of supplies is very real. The end of available reserves is in sight, if the present rate of use continues unless new deposits are discovered. "If we are to maintain during the next twenty years or by 1963 the same rate of increase in production as in the last twenty years," said a noted geologist in 1943, "it will be necessary that there be discovered the staggering amount of 80,000,000,000 barrels of new oil."

The tremendous extent of this replacement, he added, is shown by the fact that it is more than has been discovered since the beginning of the oil industry. And the crude oil reserve of the United States today is only about 17,000,000 barrels!

This is where the geologist comes into the picture. For your chief work in this field would be precisely the location of new oil deposits. This is a recent development, for when oil companies were first started, petroleum geologists were almost unknown. The few who were engaged by the companies were looked upon as useless academical appendages. What is the situation today? Geologists are held in such respect by oil companies that in 1939 Shell Oil Company alone employed 837 geologic workers in the central states to direct the search for oil. As a result, billions of barrels of crude oil reserves were located.

How will you know where to drill for oil? From your intensive study of rock formations, you will know that certain areas are favorable for its accumulation. Oil will be trapped, for example, in openings in sandstone in a typical formation or "structure" that is overhung by certain types of rock, so that it cannot escape. There are different kinds of these structural traps. As petroleum geologist, you will be acquainted with all of them and you will know, by studying the overlying layers of rock, where they are likely to be far below the surface of the earth.

In this business, you will depend largely on inference for your conclusions, for you will generally be unable to make direct inspection of the subterranean rocks. Yet your deductions will be based on evidence that is so sound and knowledge that is so scientific that you will rarely if ever end up in a blind alley. Certainly, it is thanks to these methods that the race between supply and demand for oil has so far been won by geologists.

You will understand these "investigations by inference" more clearly by putting yourself in the shoes of the petroleum geologist, and starting off with him on an exploration trip. As you drive off in your car to the territory being explored, plane tables (to map the region) and surveying instruments are the most important part of your equipment.

The first step is to make a "surface reconnaissance." This means a general investigation of the main structural features and rock layers exposed above ground. Two items to which you will pay particular attention and record with the greatest accuracy, are the direction in which the layers dip and the age of the various rocks. Your written report for this first exploratory trip will mention the oil possibilities of the region covered, but only in general terms.

The next day, you may drive back again for a more detailed or "plane table" survey. Now you will use surveying instru-

ments to calculate the actual degrees of elevation of rock layers at different points. All folds and dips, no matter how slight, will be recorded in your report, for an examination of the surface alone often enables geologists to determine the underlying structure.

Sometimes this is impossible, in which case you may resort to shallow drilling. Under your supervision, core-drill crews will make borings through the soil in order to determine the nature of the rock underneath. Before they do so, however, it would be your job to estimate the most likely spots for the borings. You will report the day's work on a geologic map, recording where you drilled and what were the results.

This exploration of buried rock is called subsurface geology. You would have to wait until you returned to the laboratory before you could tell the exact nature of the fragments of stone punched out by the drill. Peering at the samples under the microscope, like a scientific detective, hot on the trail of buried treasure, you would estimate the age of the rock, its character and thickness. All these are telltale clues in the search for the hiding place of the most valuable treasure of all: crude oil.

You may use various methods of indirect oil-prospecting. Most spectacular of all is the use of the "seismic principle" by which navigators make depth soundings at sea. When you give the signal, a small charge of dynamite is exploded. This sends waves through the earth. They are reflected back by the deep, underlying rock and an echo results. By measuring the time it takes for the echo to sound, as recorded by a sensitive instrument, you can determine the character of the intervening rock!

For example: sound travels faster through rock salt than through other types. If the echo sounded sooner than usual, you would probably feel quite elated for that would mean buried domes of salt — and this in turn is generally associated

with accumulations of oil deposits! The instrument you would use for this sounding is so sensitive that you would be able to record echoes from depths as far below the surface as three miles, even though the dynamite charge is only one pound. Seismic exploration is an expensive process. During the last ten years it has cost companies in this country over $100,000,000, but you need not pity the companies, for it has led to the discovery of more than one hundred oil fields that were commercially valuable.

The field of economic geology (mining, oil, etc.) is not a boundless one. Your work being the location of oil and mineral deposits which are limited in amount, the more thoroughly you did your work, the closer you would come to the end of all available deposits. Economic geologists are literally working themselves out of a job.

This need not concern you unduly if you have a bent for scientific exploration, for there are still many reserves to be located. If you were employed in construction work, on the other hand, there is no end to the possibilities of jobs unfolding in the future. For modern construction is impossible without the aid of geologists who must be consulted regarding such problems as the porosity of rocks or the danger of landslides.

Geologists prevent millions of dollars of waste in construction as well as saving countless lives by their rock studies. Some years ago, the government started to build a reservoir in one of the western states to store water for irrigation. The site had been recommended by a consulting engineer, who reported that it was solid and offered satisfactory foundation. Unfortunately, no geologists were consulted. When drilling began, it was noticed that water seemed to disappear as it was poured into the drill holes.

Geologists were called in. They investigated and discovered that the rocks which were to support the dam were

porous and rested on volcanic ashes. If the reservoir had been built, it would have functioned like a sieve instead of a container! The site was abandoned and a new one selected. This time, you may be sure, geologists were carefully consulted in advance, for their investigation had saved the government about $2,000,000.

Geology should appeal to all who are attracted to an outdoor life as well as science. It should interest you if you enjoy collecting rocks and birds' eggs, or planting specimens, and taking long hikes into the country. You would have to be in good health as your work may involve working long hours under all kinds of weather conditions. You might be on an expedition to the Arctic waste or into the steaming jungles of the Amazon. Or you might have to travel on horseback for hundreds of miles into the interior of primitive countries or paddle a canoe as the only available means of travel. These expeditions may be necessary for geologic mapping of oil or mineral deposits, or merely for exploration. Such work requires initiative, patience, and resourcefulness.

For preparations for your career, you should be well grounded in chemistry, physics and also biology. It has even been said that geology is more an application of these three sciences than a science in its own right. You should study modern languages, especially Spanish, for South America today offers probably the greatest opportunities for geological work.

To meet severe competition for good positions, you should have a master's degree at least and preferably a Ph.D. Your study of geology in college should include all the major divisions – physical and historical geology, mineralogy, paleontology (the study of fossils and fossil imprints in rocks), petrology (the classification of rocks), structural geology (the study of the earth's inner structure), and economic geology. If possible, you should attend additional courses in

mining engineering, history, mathematics, surveying and drawing.

While most jobs are in private industry, you could enter government service by taking civil service examinations for the United States Geological Survey. If you work for the survey, you have a choice of employment in any one of six divisions:

(1) In the geologic division, you would specialize in the composition of rocks and soil, both physically and chemically.
(2) In the topographic division, you would draw topographic maps, showing different elevations, mountain ranges, etc.
(3) In the water reservoir branch, you would make calculations of available water supply at different times. This work is especially important in certain western states where water is scarce. You would also investigate the nature and routes of water beds, methods of making water available, etc.
(4) In the conservation division, you would study rock strata in various regions and map out mineral deposits.
(5) In the Alaskan branch, you would study the topography and mineral resources in Alaska.
(6) In the administrative division, you would have charge of geologic records and statistics.

You would thus have a variety of choices, from outdoor occupations and traveling, to laboratory analysis and scholarly research in the library. The salary of geologists in the survey start at about $2,000 a year and you would ultimately be in line for important executive positions paying $6,000 to $8,000. The majority of jobs, however, pay from $3,000 to $3,500. In addition to federal positions, there are various state geologic surveys. These offer salaries from $1,200 to $5,000 a year.

The study of historical geology will attract you if you

are interested primarily in the knowledge of the various stages of development of the earth, all the way up to its two billionth birthday. You will learn to read the story in the rocks as ancient Babylonians read clay tablets. By studying the remains of prehistoric animals embedded in the stones or the imprints of animals or vegetation (paleontology), geologists are able to reconstruct past ages in considerable detail. You may learn what kinds of animals and plants existed many thousands of years ago, what man looked like, what weapons he used and how he lived. You will piece together all the evidence into a general pattern and determine the changes in climate and temperature that came over various regions of the earth; the advance and retreat of ice caps, the inundation of huge areas beneath floods and oceans, the drying up of lakes and bays. You might trace the development of land areas until they finally assumed the shape and form the continents have today.

Like all scholarly research, this branch of geology offers rewards that are richer in knowledge than in job opportunities. However, some large museums like the Smithsonian Institution in Washington, D. C., are staffed with a limited number of historical geologists. Probably your best opportunity in this field would lie in teaching. Starting as a university instructor, you might in time become a professor. In addition to teaching, you would supervise laboratory courses and also field trips.

Geology offers you not only a fascinating career, but a pair of spectacles through which you would be able to view your physical surroundings wherever you are, with new eyes and understanding. When you see a slope, you will know, by your knowledge of historical geology in that part of the country, whether it was caused, maybe millions of years ago, by the erosion of running water or by the deposits of debris carried by ancient ice sheets. In some places, like the vicinity

of Gary, Indiana, you would know it was developed by wind pressure.

Looking at the soil, you will see it not as the farmer does, but as the end result of changes through hundreds of millions of years. You will know it was part of the solid crust of the earth maybe hundreds of miles away, but that it was carried to its present position and deposited as drift by great ice sheets that had moved down from Canada. Each rock will have its own story of origin and history which you will be able to interpret.

Trained in geology, you will see your particular locality for the first time as a historical creation. You will find a constant fascination in your travels as you move to different geological surroundings. Apart from your career, you will be aware of the living earth as never before, "of what is happening to it and of what has happened to it through the ages."

As a career, geology offers you an opportunity to serve industry and science at the same time. You will literally be making a living out of the earth, and finding more than pay dirt in its depths. It is an exciting profession, with a reasonably secure income but, in the apt language of the profession, it means hard digging and long training before you reach the heights.

So once again, ask yourself: do I like it deeply enough? And do I have what it takes?

Chapter XI

A WOMAN'S PLACE IS IN THE LABORATORY

They talk about a woman's sphere,
  As though it had a limit;
There's not a place on earth or heaven –
There's not a task to mankind given –
  Without a woman in it.

KATE FIELD

IF YOU should visit the Bureau of Home Economics in the Department of Agriculture in Washington, and ask for the bureau head, you might be surprised to be ushered into the office of a woman. Her name is Dr. Louise Stanley and she is a chemist by profession. Perhaps Dr. Stanley would introduce you to the members of her staff, in which case you would be in for another surprise, for all of them are women!

Women have been traditionally associated with the kitchen, the nursery, and knitting. The only professions considered appropriate for them in the nineteenth century were nursing, midwifery and teaching. As to the various occupations based on science, they have long been thought of as essentially male occupations, requiring qualities that, presumably, are outside the province of the gentle sex.

Today, one of the trends in science as well as industry, is the growing use of women in important positions. It is difficult to mention a single field of science in which women have not been responsible for important contributions. As far as the medical profession is concerned, this is not new, since women have been famous in this field for centuries. In the writings of Galen who was born about 131 A.D., several women physicians of the time were mentioned, including Favilla, whose remedies he praised and Margaretta, an army

surgeon. Later in the seventh century, a woman named Trotula taught anatomy at medical school and her writings on the subject have been quoted for centuries.

Carrying on this tradition today is Alice Hamilton, only woman on the faculty of the Harvard Medical School. Then there is Ellen H. Richards, whose studies of sanitation have become standard textbooks. Dr. Florence Rena Sabin holds a full professorship at Johns Hopkins Medical School. She has made important contributions to research on tuberculosis. Sister Kenny is famous throughout the world for her contributions to the treatment of that dread disease of childhood, infantile paralysis.

One of the greatest authorities on cancer in America is Maud Slye, sometimes called, "the American Curie." Her life story is an illustration of the opportunity that beckons to women in the career of science.

Miss Slye — or, rather, Professor Slye, as she is now called — entered the freshman class at the University of Chicago in 1895. Interested in psychology, she later became a teacher in that subject at the Rhode Island State Normal School. Psychology led her to psychiatry, and particularly to the problems of heredity. It was as assistant to Professor C. O. Whitman, famed biologist, that her real work began. Soon she was spending eighteen hours a day and more, experimenting with mice, sterilizing the cages, breeding and crossbreeding.

One day in 1910, while inspecting her growing army of little animals, she noticed an abnormal growth on one of the mice. That was the beginning of her research into cancer. She has spent her entire life in a world of mice and performed more than 100,000 autopsies on these furry creatures.

Dr. Slye, after countless experiments, created a sensation when she read a report of her findings before the American Society for Cancer Research, entitled: *The Incidence and*

Inheritability of Spontaneous Cancer in Mice. This paper has become a medical research classic. In it she proved conclusively that cancer is inherited and not contagious. She showed also that cancer can be provoked by irritation, but only in people who have inherited a tendency for the disease. It is significant that at the same time that she received a gold medal from the Radiological Society, a medal was awarded to that other great woman pioneer in science: Madame Curie, whose discovery of radium was such a boon to sufferers from cancer.

In 1944, it was estimated that there were sixty-five women doctors in the army. At first they served only with the Women's Army Corps. Because of their excellent work, however, they were soon in demand by general hospitals as well. They worked as radiologists, pathologists, psychiatrists and general duty medical officers.

Typical was the career of Major Margaret Janeway, formerly a New York physician. She first became an army contract surgeon with the WAC in Iowa. For fourteen months, she served overseas as head physician for the WAC in Italy and North Africa, with the most extensive record of foreign service of any American woman doctor.

Chemistry is another field in which women have distinguished themselves. Dr. Emma Perry Carr of Mount Holyoke College, for example, has won numerous honors for research in petroleum hydrocarbons. The same is true of Dr. Dorothy Wrinch, well known for her work on the structure of insulin. Head of the Technical Laboratories of Sears Roebuck in Chicago, is Dr. Elizabeth S. Weirick, outstanding textile chemist, with an assisting staff of eighty-one scientists, of whom eleven are women.

Consider, even, the male-dominated field of physics. Said Dr. Langmuir, Nobel Prize winner in chemistry, of Dr. Katherine Blodgett, his associate for twenty-two years in

the General Electric Research Laboratory: "She has that rare combination of theoretical and practical ability." Dr. Blodgett's most famous contribution is the discovery of "invisible" glass, which may blaze a new path in glass technology. Or consider the field of astrophysics or astronomy. If you have never heard of a woman squinting through a giant telescope, you should meet Dr. Annie Jump Cannon. She has identified and classified more stars in the heavens than any male astronomer: nearly 400,000 of them! It was probably due to chance contact with Dr. Pickering, then director of the Harvard Observatory back in 1897, that she was given an opportunity to show what she could do. For Dr. Pickering, contrary to the prevailing opinion that a woman's place is in the home and not in the observatory, appointed her his assistant. Since then, she has been the recipient of many honors and was the first woman ever to receive a gold medal from the American National Academy of Sciences.

Another distinguished astronomer is Henrietta Leavitt of the same observatory. Dr. Leavitt is well known in astronomy for her discovery of the "period-luminosity law." By means of this law, it was possible for the first time to calculate the position of many stars in the universe.

You might agree that women have won their wings in medicine, chemistry, and physics; but what, you might ask, about engineering? Here is a profession that is the very essence of maleness! One instinctively visualizes a heavy-handed man, perhaps in dungarees, directing gangs in rough terrain as a bridge is being constructed. Yet even here women, though not so heavy-handed, are distinguishing themselves equally. For example, meet Alice C. Goff, one of three women who are licensed to practice engineering in the State of Ohio.

Miss Goff, as a structural engineer, is designer and esti-

mator for the Truscon Steel Company. Her work is in connection with reinforced concrete buildings. The architect works out the arrangement of a building to serve its particular purpose, and plans the desired external appearance. Then, as engineer, she figures out the framework of reinforced concrete to support the building. Floor slabs must be designed to carry dead loads and anticipated live loads. Beams are figured to carry slabs, and columns to support beams, at proper stresses. Loads from various floors are carried down through the columns onto foundations, which must be designed to support them at safe soil pressure. After the design is completed she estimates the quantities of steel and of concrete needed in order to determine costs.

In the important field of aeronautical engineering, there is Mrs. Donald H. Marquis, graduate engineer and licensed pilot, working for General Electric. A particularly distinguished representative of the fair sex in electrical engineering is Edith Clarke, one of three women who are members of the American Institute of Electrical Engineers and the first woman to win a degree in electrical engineering at the Massachusetts Institute of Technology. A second member of the institute is Mrs. Mabel McFerran Rockwell, production research engineer for Lockheed Aircraft Corporation in California. She helped to design the electric power systems for the Colorado River Aqueduct. At present she directs twenty engineers doing research in airplane shop processes, and not one of them, you can be sure, objects to the fact that their boss is a woman!

Among women as among men, the future in science belongs to youth. For example, Mrs. Josephine Webb. At this writing, she is only twenty-six and is a full-fledged electrical engineer engaged in research on electronic tubes. Then there is Miss Lois Coots, also twenty-five and assistant to the Chief of Research and Education in the U. S. Weather Bureau. Julia

Senko was formerly a chemist in the industrial hygiene department of Westinghouse Electric. At thirty, she became a microchemist in the company's research laboratories, where she uses midget beakers, crucibles and test tubes to make chemical analyses of tiny flakes of rust and tarnish that harm electrical equipment.

Or turn the spotlight on Carmen Venegas, young Costa Rican electrical and application engineer in the Government Department of the Westinghouse Electric International Company. Educated in the United States on scholarships, she said that she chose this country for her training because she had "heard so much about the freedom and opportunities available for women."

That this freedom and these opportunities exist is shown also in chemical engineering. For example, consider the case of Mildred Pfister, licensed to practice not only chemical but electrical and technical engineering as well! Formerly consultant on water conditioning and corrosion control in steam plants, she is now a special consultant on foods, special processes and machinery. Miss Pfister shows by example what women can do in all branches of engineering as well as in science in general.

Women geologists and paleontologists are today playing an important role in the oil industry, another field traditionally dominated by males. Working with maps and microscopes, they are responsible with their male associates for the opening of valuable oil fields throughout the country.

Consider the discoveries of Mrs. Fanny Carter Edson, chief geologist of Cimarron Petroleum Corporation. The first woman ever to graduate from the University of Wisconsin with a geology degree, she took a master's degree in petroleum geology and was hired by an oil company to work in Oklahoma. While studying samples of oil well drillings, under the microscope, she noticed minute bits of semi-precious

stones, like garnet and topaz. She wondered if these fragments could not be used to identify each type of oil-producing formation, so that oil sands apparently the same could be shown to be different by analysis of the stones.

Developing her theory, she applied it one day in dramatic fashion when she insisted that her company drill deeper in a certain wildcat well, after only a small amount of oil had been found. By analyzing the samples of sand by her method, Mrs. Edson concluded it was not the type she was seeking which was buried deeper. The drillers swore, for the sand hardened into quartz as they continued. They were proceeding at the rate of only one foot a day and were about to abandon the attempt and go back to their former level.

Mrs. Edson, however, put up strong opposition and they finally continued. At eighty feet they struck a new layer of sand and suddenly oil gushed out with such force that it was impossible to remove the tools. Thanks to the jewel theory, Mrs. Edson had discovered the Marshall pool which has produced 15,000,000 barrels of oil and is still producing!

It is characteristic of Mrs. Edson that her method led her to the collection and study of these jewels, so that she became an authority on precious stones as well. Not only amateurs, but even professional jewelers now bring stones for Mrs. Edson to appraise!

All over the country, there are thousands of such women, enjoying their professional work that is so vital for the health and welfare of the nation. They compete with men on an equal footing. They win their way by hard study and rigorous training. They are chosen because they deserve to be for, less and less, as the need for trained experts increases with the expansion of science and industry, is sex a barrier to employment and promotion.

Even before the war, the notion of women as creatures who are fitted only for "genteel" occupations was widely ridiculed

as a hang-over from the Victorian age. The war broke down occupational barriers between the sexes. Today exhausting work and physical hardship are no longer earmarked for males only. The drive for knowledge and a career in science has given the so-called weaker sex the strength to overcome every obstacle. Consider the work of meteorologists. This requires going out-of-doors in sub-zero weather, lifting heavy cylinders of helium and working irregular hours. Because of this, no women were employed by the United States Weather Bureau prior to the war. But in 1941, the bureau was asked by the Civil Service Commission to experiment with the employment of women meteorologists. They proved so satisfactory that the bureau is now training women for the first time. Several have already been assigned to government stations in various parts of the country.

As in meteorology, so in other scientific fields. The war has opened up undreamed of opportunities for women who are eager to prove their worth. The jobs are waiting, so is the opportunity for advancement. What is needed, besides ambition and the proper personal qualifications, is training and education. And there, too, the war has worked a tremendous change in conditions. Schools and colleges that used to admit only a minimum number of women for certain courses have let down the bars so that this is no longer an obstacle. It has always been an open secret, for example, that young women have found it more difficult than men to be admitted into grade A medical schools, as well as engineering schools. Today, this is no longer true. The scarcity of professionals for civilian needs has forced them not only to open their doors, but to cordially welcome young women. Indeed, the demand is so great that high school students with exceptional records are sometimes given their diplomas before they graduate, so that they can enter college at once. In addition, special two year college courses for women qualifying them

for technical positions, have been established. Nor is there any difficulty obtaining employment after training. Certain industries, working in co-operation with the colleges during war, offer training to women for immediate war jobs even while they are attending class.

It is true that many such positions will vanish when the war is over and service men return, but this does not alter the fact that women are proving themselves in science and that they are in this field to stay. The experiences of the first World War show that opportunities for women created by war conditions can lead to permanent recognition that they never enjoyed before in these fields. Some lost their jobs, but others did not and the important fact is that many barriers based on prejudice were permanently abolished. It is not the specific job or how long it lasts that matters for the future of women in science. It is the over-all picture of what women have proven they can accomplish that is important.

That women will continue to be used in increasing numbers after the war in American industry, was emphasized by Mrs. Warwick B. Hobart, adviser of employment of women for the Secretary of War. In a speech before the Industrial Hygiene Foundation in November, 1943, she said: "Management's experience with the employment of women has on the whole been very satisfactory from a production point of view. The results will be that after the war all industries will have a very much larger percentage of women," and she added that many will continue to be employed "because management prefers them to men, having discovered that many women have very high skills which were never utilized before."

Referring to the increase of women chemists in recent years, Dr. Helen I. Miner said in a recent report to the American Chemical Society, "Conclusion of the war will not con-

tract this extended horizon for women chemists. In the reconstruction period which must follow, there still will be acute needs for trained Americans of both sexes to assist in the multitude of problems, nutritional, medical, agricultural, and industrial — which must be solved in winning the peace." She added that since Pearl Harbor, the number of technically trained women on the staff of a certain fuel corporation has increased by 450 per cent!

Today, thousands of women, trained in physics, chemistry, geology, biology, are busily engaged in industry and research. They are proving themselves in soil chemistry, medicine, industrial research, engineering, teaching, textiles. But that is only a beginning. For these fields are expanding, some of them like electronics or plastics, at an amazing rate. That means that more women as well as men who are trained in the sciences, will be needed in the postwar world. And the recognition of women in fields where they were formerly unknown is bound to increase sharply with the demand. It is significant that some of the biggest oil companies have taken the initiative in establishing courses giving specialized training to women in various branches of geology. Significant, because oil companies would hardly be motivated by gallantry alone in their choice of trained technicians!

Remuneration for women in scientific careers is about the same as for men. That this is not limited to the war years is shown by the fact that long before the war this situation prevailed, in most cases. Thus in 1932, of a group of 353 women chemists reporting salaries, about one-third earned less than $2,100 a year; one-third earned between $2,100 and $2,999 and the rest earned $3,000 or over. This compares favorably with the amount received by male chemists in the same year, which was a depression period.

A woman's place is in the laboratory *as well as* the home!

Only she will have to toe the mark and meet the necessary qualifications, for science is a hard taskmaster and knows no favoritism or special privileges on account of sex.

And so, young lady, if you are thinking of a career in science, you must ask yourself the crucial questions: Have I got what it takes? Am I prepared to pay the price?

Chapter XII

FUTURAMA

In the postwar, plastic age,
  Won't you feel elated,
Riding in a taxi-plane
  To homes prefabricated!

You will have a six course meal
  In a single pellet;
Clothing will be made of milk,
  Though you'd never tell it!

Home will daily cleanse itself,
  Isn't that ironic?
You won't have to lift a hand,
  Thanks to "electronic."

Writers like myself, I fear,
  Will be on the shelf;
For, by then, a book like this
  Will quickly write itself!

"When the war ends, at least 56,000,000 Americans are going to want jobs. That is 10,000,000 more than had jobs in 1940, our last peacetime year."

So said Paul G. Hoffman, chairman of the Committee for Economic Development in September, 1943.

Will science be able to furnish jobs for these men and women? The answer is yes, according to a survey conducted by Guarantee Trust Company. Under the spur of wartime necessity, research scientists and engineers have packed approximately ten to fifteen years of development work into

the first two years that the United States has been at war.

According to the survey, thousands of added scientists and technicians will be needed in the greatly expanded fields of aviation, electronics, plastics, chemicals, light metals. The report stressed the growth of electronics in particular, pointing out that 750 different kinds of electronic tubes are already in use. It was calculated that the total value of the products of this industry alone for 1943 was expected to surpass that of the entire automobile industry in the prewar period.

Then there is that magical child of aeronautical research: radar. Practical applications for this science are growing, from its use in radio and television to cooking and the treatment of diseases. Or consider the light metals: aluminum and magnesium are today as familiar as wrought iron was fifty years ago. Will they in turn be replaced by new metal products of the research laboratory like tantalum (used in radio tubes), indium, which is softer than lead, beryllium, which is a third lighter than aluminum?

Helicopters, higher octane fuels and superior Diesel engines are only signposts to a postwar future in aviation that will call for thousands of research physicists. Already, Juan T. Trippe, president of the Pan American Airways System, is planning for Flying Clippers that will wing their way across the Atlantic seaboard to London in less than 14 hours with 150 passengers on board. One of his projected schedules would provide for a weekend in Paris, the traveler having lunch on Friday in New York, breakfast the next morning in Paris, with two days of sightseeing and then returning to New York again in time for an early Monday breakfast so that he can show up bright and early at his office to start the week's work. And the entire round trip would cost only $202.50!

As to the research chemist, the postwar future will pour increasing opportunities into his lap. In the field of plastics

alone, demand for his services will increase tremendously. Chemists are already experimenting with plastic houses, trains and boats as well as furniture. The lowly carrot yields a plastic that has been found to be excellent for chairs and tables! If you examine springs under the microscope some fifty years from now, you may be amazed to discover they are made from the material of sponge instead of steel. Table linens of the future may well come not from textiles but from the redwood tree. In 2000 A.D., John Q. Citizen may bathe in a plastic bathtub that will be permanently free of chips and cracks. He will rest in a chair upholstered in plastic and will hear music from his radio set or phonograph that will sound all the finer because of the plastic diaphragms. He will not have to worry too much about his laundry bills, either. If he uses a cheaper grade of sheets, pillow cases, towels and even rugs, he will throw them away when they get soiled like paper napkins, and buy new ones, for they will be made out of plastic-soaked paper! But that is not all. He will be living in an apartment that is warm in the winter, without benefit of coal or oil in the furnace. On the window sill will be small cabinets that suck in the winter air, extract heat from it, and waft the heat indoors.

Perhaps he will want to make a phone call to a friend who lives in another city. He would dial the number as you do today, but with this difference: his instrument would not be connected with telephone wires to a telephone exchange, for it would be a radiophone. At his friend's home, the radiophone bell would ring as the radio waves connected and his friend would pick up the receiver.

If John Q. Citizen is married, he will not bicker with his wife because he wants to hear the baseball news while she wants to listen to the reports of the fashion show. With two radio sets in the room, each will be able to listen to his own program without interference from the other; each set of

radio waves will be focused like light rays on the spot where the listener is seated.

As to the radio set itself, it will probably look quite different from the radio of today. It will in fact be a combination radio, television set, phonograph, motion picture projector and "talking book!" If John is interested in a book, but is too tired to read it, he need only turn a switch and a beam automatically scanning each line of the open book will be converted into the inflections of a human voice that will read the sentences to him aloud.

This same "radio set" will have another function. During the night, it will quietly operate a printing machine, receiving copy and pictures through the air from the printing plant of his favorite morning newspaper, and duplicating them so that a miniature newspaper, complete with cartoons and headlines, will be on his table in the morning.

John's automobile will be quite different, too. For one thing, he will look at his dashboard to see the changing traffic lights instead of street corner lamps. Or, if he has no car, he might hail a helicopter taxi-plane, for four wheeled taxicabs may be outdated. In the coldest weather, the windows of the plane will be open, yet John will be warm, for his body will be heated by radio-frequency waves, warming the body internally so that external heat is not necessary.

There has been considerable discussion regarding the authenticity of this postwar picture. Authorities have pooh-poohed the possibilities of these inventions as products of a Jules Verne imagination. They point out that there are serious obstacles, scientific, engineering, and economic, to their realization, and that they will not materialize to the point where they can be made available to the masses for a long time.

An examination of this argument reveals that the only point of disagreement is the time interval. Certainly, it would

be inaccurate to state that helicopter taxi-planes or "talking books" will be widely used twenty-five or even one hundred years from now. The significant point from the viewpoint of the postwar future and its relationship to scientific careers, however, is that they will finally be perfected and used.

Even a "talking book" is no more miraculous in achievement relative to the level of science today than radar and television would have been to the layman of 1890. Far from being Utopian notions, these projected inventions are in the logical line of development of the miraculous machines of 1944. They will be your goals when you embark on your scientific career. Neither you nor your colleagues might be able to encompass them within the span of your generation, but your work may well bring the world a foot or an inch nearer to their realization.

As to those who state dogmatically that universal use of helicopters for daily use is a scientist's pipe dream and that the plane will never supplant the automobile as a regular means of transportation, the following quotation from an article that appeared in 1900 in the *Reader's Digest* (quoted in *The March of Science* by H. Gordon Garbedian) is significant:

"The ordinary horseless carriage is at present a luxury for the wealthy and although its price will probably fall in the future, it will never of course come into as common use as the bicycle."

Substitute "helicopter" for "horseless carriage" and "automobile" for "bicycle." Would not this "prediction" be just as rash?

Scientific discoveries teach us not to place limits on the possibilities of aeronautical discoveries in the postwar future. Take the question of speed. That airplanes may some day travel at the speed of sound was claimed by no less an authority than Dr. Theodore von Karman, director of the Guggen-

heim Aeronautical Laboratory, California Institute of Technology.

"Obviously," he said, "it is an interesting question whether there are any intrinsic limits for flight velocity. Many people will ask you 'shall we ever fly faster than sound?' I do not believe that at the present time this question can be answered by a straight yes or no."

In addition to new processes and applications developed by the needs of industry in a nation at war, are the amazing military inventions which are in some cases adapted for industrial purposes. The tank gun stabilizer, for example. This was invented in response to army needs for guns that will fire accurately even from a tank that is in bumpy movement over shell-pocked terrain. Called a "gyro-stabilizer," it keeps the tank gun's barrel at an approximately fixed elevation and also the target in focus of the gunner's telescopic sight, in spite of the changing pitch of the tank. Scientists predict that the principle of this device will be used to make passenger trains ride more smoothly over rough roadbeds; also to hold automobile bodies on a more even keel on bumpy highways.

Then there are the thousands of rich, unexploited ideas found in patents seized in enemy countries and held by the Alien Property Custodian. These offer relatively untapped sources of new and improved devices, products and techniques, as well as machinery and equipment. Already in September, 1943, 40,794 of these items were listed.

Standing on a higher postwar level of science and industrial technique as a result of all these developments, who can doubt that mankind will reach yet higher levels than seem possible today? Science has shown that the "impossible" is possible in so many fields that perhaps the word should be deleted from a scientist's vocabulary. When Marcellin Berthelot, French synthetic chemist, predicted that John Q. Citizen would some day be eating synthetic food in the form

of three small pellets a day, equivalent to three full-sized meals, there were many who smiled at this "Utopian" notion.

Professor E. C. Baly of the University of Liverpool did not smile, for he had succeeded in making sugar synthetically by exposing water, containing dissolved carbon dioxide, to ultra-violet rays and changing it into a sugary substance. Here is the crude beginning of a synthetic sugar and starch industry. It might take 50 or 150 years to develop, but the direction points to a coming big change in the fields of sugar beet and cane farming. All that the farmer will then need is coal and water. Instead of ploughing the soil and planting seeds, he will be watching and regulating pressure gauges and switching on ultraviolet lamps, as synthetic sugar curdles in huge vats!

If you had visited the home of William V. C. Ruxton, New York City, in July, 1944, you would have witnessed an exhibit put on by the Society of Chemical Horticulturists, that was little less amazing. Growing out of sand and nurtured by chemicals dissolved in water, a corn patch flourished on the roof, alongside ripe tomatoes and a model garden for a South Pacific island. The exhibit was held "to demonstrate the possibilities of soil-less gardening and methods of growing plants under this system."

It is a much more complicated problem to create synthetic proteins, the substance found in meat and egg yolk. No doubt this achievement belongs to the remote future, but even this may not be too far off. Already, Emil Fischer won the Nobel prize for his startling laboratory duplication of the albumin of an egg (synthetic peptides).

In 1940, American industry spent $220,000,000 for research, according to Dr. William A. Hamor, associate director of the Mellon Institute of Industrial Research. The figure rose to $275,000,000 in 1941 and $300,000,000 in 1942. This increasing support of scientific research by hardheaded busi-

ness men and industrialists is a guarantee of expanded scientific careers and vocational opportunities.

What are the concrete, practical fruits of this research, already achieved but not yet used? You can get a glimpse of them and of the world of tomorrow by reading a report issued in the summer of 1943 by the Research Advisory Group. This report was based on a survey made by twenty-six scientists and leaders in industrial research. You can be sure that no "Utopian notions" were included, as the survey was sponsored by the National Association of Manufacturers, whose members plan to invest many millions of dollars in the manufacture of postwar products.

The report lists new inventions and processes ready to be applied or put on the market. They resemble in their entirety an engineer's blueprint of the immediate postwar future and emphasize anew the growing importance of research scientists in industry. Here are a few of these developments:

An electrolytic process for tin plating that will save 60 to 70 per cent of the metal lost in the operation; a method of transforming soft woods into hard woods by the use of new resins; the "welding" of rubber parts by thermoplastic means – that is, the use of radio frequency as a sewing machine to stitch them together; the production of pure hydrocarbons for the first time – an important discovery in oil refining.

Among new inventions in industrial equipment reported were an improved gas turbine, new electrified tools, improved electronic instruments to record defects in materials, vitreous clay battery boxes, an electrically driven chain saw operated by a high frequency generator.

For transportation: the helicopter, new light metal buses designed for high octane gasoline, the wide application of radar for piloting ships and airplanes through fog, turbine-driven locomotives that use 25 per cent less steam.

For the improvement of public health, the use of high frequency currents instead of gas for cooking, synthetic spices like cinnamon, a new synthetic food made by flour milling companies, a method of making sea water drinkable, penicillin, and other new chemicals to combat diseases more effectively.

Said a steel manufacturer: "We feel that one of the most important requirements for postwar prosperity is the development of new products and processes."

Why new products and processes? Because the present ones, miraculous though they seemed when first developed, are no longer good enough. Take the automotive industry. It is the biggest power-creating industry in the world. And yet Charles F. Kettering, inventor of the automobile self-starter, admitted that too much fuel is wasted needlessly in gasoline engines which have a "thermal efficiency" of only 10 per cent on the average.

The gasoline itself is by no means what it should be by today's standards. True, it has improved greatly since the first World War when 50 octane was tops and the best engine was 450 horsepower (compared with 100 octane gas and 2200 horsepower now obtainable). Yet today's product soon will be outmoded, say scientists, owing to the revolution in oil refining that has been going on since prewar days.

Aside from the development of new processes and techniques, thousands of scientists and technicians will be needed in industry for the production of radios, clocks, automobiles, refrigerators. The American people have been forced to do without these articles for the duration. Manufacturers will be forced not only to satisfy a famished demand but also to replace articles which have been worn out. This is expected by many economists to result in a boom in industry that will require science-trained men and women to a larger extent than ever before.

Proof of this is the following: the Committee for Economic Development has set as its postwar goal an output of goods and services that will be greater by 40 per cent than the level of 1940. This means keener competition for markets and more attention than ever before to quality of products. Laboratory research to improve these products will itself be a booming activity. Indeed, this boom has already begun. Even the candy industry is not exempt. It has appointed a special research committee to discover new ingredients to improve candy food value and vitamin content. It is also co-operating with the Department of Agriculture in experiments designed to use more farm products in the making of candy.

Again, in the textile industry, scientific research is moving in high gear, with plans for a central institute of research to be supported by all organizations in the industry. Physicists as well as chemists will be employed, for electronic principles are being applied to an increasing extent in textile manufacturing. One of the problems that will be investigated is the creation of wool that is proof against moths. Recently, the Textile Research Institute started a drive for $300,000 a year for a five year period for scientific research. The institute's plans include a carefully prepared program of fundamental (theoretical) research and applied (practical) research, and also a graduate school that will be affiliated with a leading university. This highlights again the recognized commercial importance of research to industry.

In the field of radio, apart from television, the new process called "frequency modulation" (FM) promises to open a new era for radio broadcasting immediately after the war. At present there are about 50 FM stations in operation. Five years after the war, there will be 500, according to officials of General Electric! One authority predicted that the new process would be available to 85 to 90 per cent of the present

listening audience within a few years after hostilities cease. So fast have been developments in research laboratories that some authorities have claimed that radio sets without an FM band will soon be obsolete. There is no doubt about the immediate post-war future for radio scientists: 12,500,000 new radio sets will be in demand when the soldiers don mufti again.

Plans for expansion of television broadcasting are also under way with tremendous increase in the number of sets to be manufactured. In 1941, the United States Government had authorized commercial operation of television stations, but the outbreak of the war put a halt to these plans. Elaborate experimentation since that time, however, has improved the process of transmission considerably for war purposes. Already the quality of the pictures on the screen is approximately equal to that of good home movies. At a New York demonstration, a new device called a Schmidt camera was used. The picture was fifteen feet high and twenty feet wide and was almost as bright as a motion picture!

To add to these improvements is projection television which will project the image on the wall of your living room, thus converting every room into a miniature movie house. One radio manufacturer has already announced that it will be ready for distribution on a mass basis soon after hostilities cease, for less than $300.

All these developments, so important to manufacturers, wholesalers, and retailers, from a merchandising and sales viewpoint, are equally important to scientists and technicians in terms of jobs and careers. Private industry already employs the great majority of this group. With greatly accelerated demand for the latest products of the scientist's laboratory, will come a stepped-up demand for research men and women as well as executives and technicians.

This will be reflected in larger budgets for scientific research. The day is past when manufacturers look upon

scientists as unprofitable and risky investments. Now it is the manufacturer himself who is willing to gamble on the research man – and with his own money! Said the president of a drug manufacturing firm while discussing experiments on the administering of insulin by mouth instead of the painful method of needle injection: "We have no assurance that we shall succeed. There may be inherent reasons why insulin can never be given by mouth. All research is like that. It is a gamble." The significant point is not the fact that research is a gamble but that progressive business men and manufacturers today are willing to underwrite that gamble!

In this manufacturer's own field, ten pharmaceutical concerns alone spend $8,000,000 to $10,000,000 a year on research. They employ more than a thousand scientists of all kinds – physiologists, pathologists, bacteriologists, biochemists, biophysicists, etc.

The immediate prospects for postwar expansion in science are thus unusually bright both in terms of products and processes already developed and tested and waiting to be used; and in terms of capital that private industry is willing to invest for expansion and research. But the prospects are immeasurably brighter if the word "postwar" is widened to include the entire generation following the end of the war.

Wonderful as are the achievements of chemurgy, for example, they are as nothing compared to its as yet unrealized possibilities. The substitution of agricultural products for metal may well reach the stage whereby five pounds of soybean will replace 25 pounds of steel in the construction of an automobile. It has been predicted that eventually the manufacture of 1,000,000 cars would consume 170,000 [illegible] of agricultural products – and this is typical of the pro[illegible] that would engage you if you became a research sc[illegible] this field.

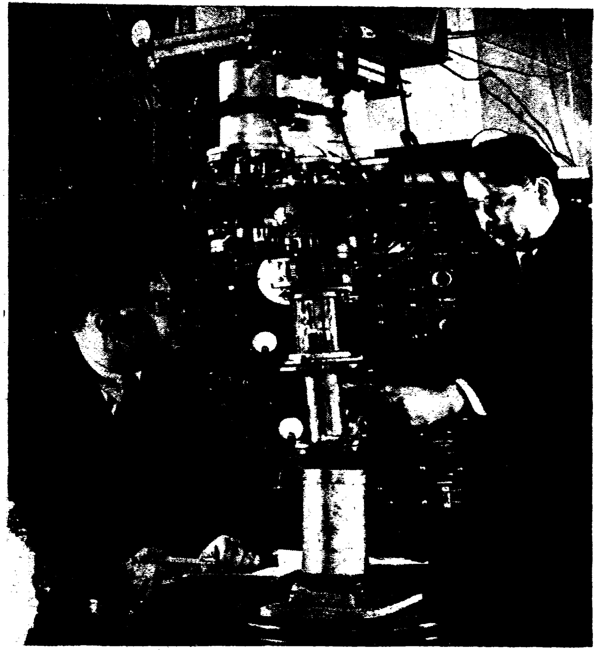
If your career is in medical research, you will find that



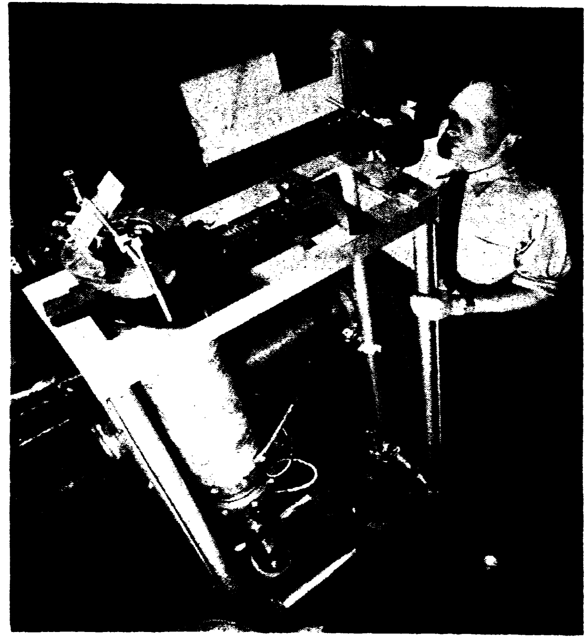
A bacteriologist in the Food and Drug Administration tests for potency of penicillin.
(U. S. CIVIL SERVICE COMMISSION)



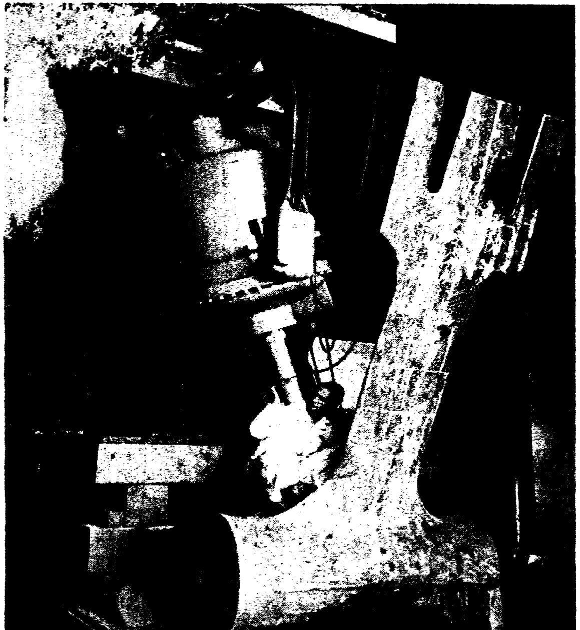
Astronomer in the Time Service Division, U. S. Naval Observatory, checks chronograph record of time signal being sent and received (for time lag)
(U. S. CIVIL SERVICE COMMISSION)



. ...ald E. Hill, research physicist (right), and
... U Condon, associate director of Westing-
house Research Laboratories, at target of 90-ton
electrostatic generator, or atom-smasher.
(WESTINGHOUSE)



Dr. Sidney Siegel, Westinghouse Research Fellow, with vacuum electric furnace in which he makes single crystals of gold and copper atoms.
(WESTINGHOUSE)



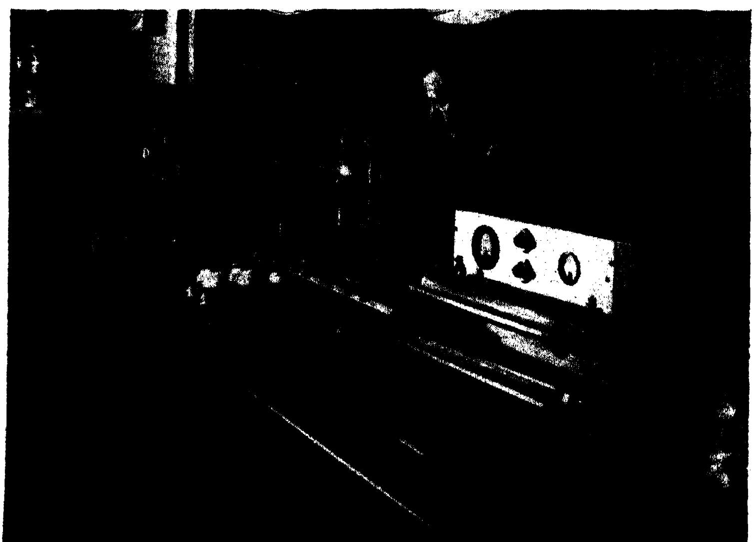
X-ray technician sets a 1500-pound X-ograph unit to record stress areas in a destroyer propellor shaft. (U. S. STEEL CORPORATION)



With his $2,400 Westinghouse Science Grand Scholarship, Paul Erhard Teschan, entered Carleton College, Northfield, Minn. He will specialize in chemotherapy. (WESTINGHOUSE)



Dr. Irving Langmuir performs molecular film experiment. For work of this type, he won a Nobel Prize in Chemistry.
(GENERAL ELECTRIC)



Spectrochemical analyst sets up his apparatus.
(BELL TELEPHONE LABORATORIES)

recent discoveries in vitamins, drugs and vaccines are only preludes to still greater discoveries to come. Will medical science be able to prolong the span of life and arrest the onset of decay? Recent discoveries point in this direction. Consider the vitamin called pantothenic acid. Fed in daily doses to black rats from infancy on, it was found that it prevents the hair from turning gray, increases their rate of growth and lengthens their life span. By absorption of another type of vitamin, hair that was already turning gray was made to turn dark. Scientists at Rockefeller Institute even succeeded experimentally in preventing baldness under certain conditions by the use of B complex vitamin.

Developments in nutrition suggest the imminence of important discoveries that will be powerful weapons in the fight against disease. It is known, for instance, that the people of northern India are hardy and strong, while the people of southern India waste away from diseases. Why? To find out, healthy rats were divided into two groups: one group was fed the diet characteristic of northern Indians and the other group the diet prevailing in the south of India. The former group waxed strong and reached an age that is equivalent to fifty years of human life. The other group during the same period succumbed to no less than thirty-nine diseases.

These experiments are signs pointing to greater discoveries in the future. Major medical problems still waiting to be solved include the prevention of typhus, leukemia (called "cancer of the blood" and as yet incurable), and arthritis, as well as cancer and heart disease. Recent advances in knowledge of hormones, vitamins and drugs, bring nearer the answer to these problems. New scientific apparatus such as the electron microscope throw light into dark corners of nature for the first time.

In 1770 the far-seeing Benjamin Franklin wrote to Dr. Priestley, famous chemist: "The rapid progress true science

now makes occasions my regretting sometimes that I was born too soon. It is impossible to imagine the heights to which we may be carried in a thousand years, the power of man over matter. . . . All diseases may by sure means be prevented or cured, not excepting even that of old age and our lives lengthened at pleasure, even beyond the antediluvian standard."

In the generation of postwar science, who can place limits to the possibilities of discovery? In view of the incredible advances of science in the last twenty-five years, who can say that no progress will be made in unharnessing the energy locked up in that prime source of power – the ordinary atom? This "imagineering" if realized, would turn the most ordinary object within your reach into a colossal power plant. A mere dream? Every fresh experiment in atom-splitting with the cyclotron brings it nearer to realization.

Meanwhile the sun keeps burning away millions and millions of ergs of energy every day in futile waste, so that in temperate zones, each acre of ground receives enough heat in three summer months to equal that of 250 tons of burning coal. Can this tremendous power plant be utilized to move the wheels and gears of industry? Utopian? The Massachusetts Institute of Technology does not think so. It is spending $500,000 in experiments on the problem. The Smithsonian Institution also has done research along the same line. The "photovoltaic cell" points the way, perhaps; a number of these cells generate enough electricity when exposed to sunlight to run a small electric motor.

"I have seen the future and it works." These words by the late Lincoln Steffens, used in another connection, might well be applied to the coming marvels of science. If it is true that science is on the threshold of important new discoveries and inventions in chemistry, physics, medicine, geology, botany, agriculture, etc., then it follows that the demand for scientists

will be much greater than ever before. This will be true even if there should be a temporary postwar lag while industry reconverts back to normal civilian production.

The number of scientists in all fields has been seriously cut down by the war. As early as October, 1943, the American Chemical Society, through its committee on the professional training of chemists, reported there was a dearth of chemists. It added that within a year or two, no more fully trained students would be graduated in the chemical and chemical engineering fields.

Similar situations have been reported by organizations representing physicists, agricultural scientists and medical scientists. The draft and war casualties have depleted the ranks at a time when the forward advance of science has called for more practitioners than before.

In the words of Dr. George Washington Carver: "With all the advancement of science, there is still an unlimited field for the creative mind. We have only skimmed the surface. What has been done is nothing compared to what will be done in years to come!"

The opportunity is there in abundance. To the science-trained young man or woman of today, the future beckons excitedly. But remember – the future belongs only to those who prepare for it, and to those who have what it takes. Your career in science is waiting. The curtain is about to go up.

Have you the price of admission?

SUPPLEMENT

THE OUTLOOK FOR THE PHYSICIST AND PROSPECTIVE PHYSICIST IN INDUSTRY

By Dr. Albert W. Hull

Assistant Director,
General Electric Research Laboratory

The coming year will be a transition period for physicists. Many will be released from war work and will be faced with the problem of deciding what they are to do. Industrial physics is one of the opportunities that will be open to them. They will want to know what it is like, what salary it offers, and what the demand for industrial physicists will be. A discussion of these questions therefore is appropriate.

NATURE OF THE JOB

As to the nature of the job, it's a hard life. Abandon all hope of ease, ye who enter industrial physics! Your days will be filled with insoluble problems, your evenings with the never-ending struggle, by scientific reading, to keep abreast of knowledge in an ever-widening range of subjects. Your job, like a woman's, will never be done. Like a man without a country, you will never be able to settle down into a groove and say that this is my home, my job. You will be an absent-minded husband, a preoccupied father, a poor playboy.

But it's an interesting life. There is a rainbow at the end of each day's journey, a thrill in each morning's anticipation of the tasks ahead. Life is a continual game, a contest with

nature, which always plays fair. The harder the problem, the greater the satisfaction in its solution. Only insoluble problems desired, please!

The physicist's life is interesting, not in spite of the fact that it is hard, but because of it. Who invented the idea that an easy job is a good job? Does anyone really enjoy an easy life? No worries, hence no thrills; security, hence staticism. Those who wish such a life should not enter the field of physics. When I was very young, I worked for a short time in a factory making wooden caster-rolls. My job was to use the scrap ends that were left from the big lathes. I envied the men on those lathes; asked if I might have a piece rate like them, and was advised that I would fare better with a day rate, but insisted. In three weeks, I was making twice as much as the men on the big lathes. But that is not the important point. It is that I enjoyed my job. Noon came too soon. I enjoyed it because there was an incentive to do a better job each day.

I believe that this challenge to do a better job each day is the thing which makes the physicist's life interesting. It is inherent in the nature of his job. The ocean of scientific ignorance is so vast that Truth is forever beyond reach. The goal of each day's work is to get one step nearer to Truth.

I used to play chess with a colleague who was much my superior and invariably won. But he never allowed the game to stop short of mate. "You may not win," he said, "but you still can make a good move. There is no position on the board, short of mate, in which an excellent move cannot be made." To him chess was a series of good moves. The physicist's job is a series of good moves. In the contest with Nature, he never wins, but always can make a good move. And the pleasure of the game is in the moves, rather than in winning.

What I have been saying about physics, is, of course, true of other sciences, and might apply to any kind of job.

Mr. Charles E. Wilson, former president of the General Electric Company, who is now Vice Chairman of the War Production Board, has been urging war industries to adopt "incentive pay"—more pay for more production – as a means of increasing war output. Such an incentive could transform any job from being easy, and hence dull, to a contest with perfection, which is the type of job we have been discussing. The implementing of such incentive plans is in itself a task of this kind, difficult and impossible of perfect accomplishment, but susceptible to progress; an opportunity for good moves by labor and management.

It is not to be expected that the same incentive will appeal to everyone. For example, a young man who was working in our laboratory some years ago asked to be transferred to the vacuum-tube engineering department, with the comment "I want to make tubes that work." The research method of testing each day's product to destruction, in order to learn as much as possible, left him unsatisfied. His was a temperament that craved fixed rules and attainable objectives. Another man left our laboratory for the commercial department. He wanted more social contacts than were afforded by research work. Such changes are to be commended. The most important part of education is finding out what one most enjoys doing, and the final test of this is actual trial, which should be made as early as possible. One method of determining this is summer work, such as a summer in an industrial laboratory. For several years before the war our laboratory invited a limited number of young men to come and work for the summer, not for what they might accomplish, but as a means of mutual acquaintance, and as a test of their fitness and aptitude for research.

A good criterion of qualification for a physicist's career is one's reaction to the report that something can't be done, or has been tried without success. A personal example, if it

may be pardoned, will illustrate this. In 1914, Sir William Bragg came to our laboratory and described, in his delightful manner, his pioneer work on X-ray crystal analysis. At the end of the lecture I inquired whether he had determined the structure of iron, which was of interest for the light it might throw on magnetism. He said, "No, we have tried it, but haven't succeeded." The next day I began working on X-ray crystal analysis. To a physicist the statement, "I have tried and failed," is a stronger challenge than any amount of advice.

To summarize: The physicist's job is one requiring hard work, in which the most important happiness-factor is the challenge of his task. For the real physicist, the one who has found the right job, this anticipation and joy of accomplishment outrank the other important incentives of salary, pleasant working conditions and public applause. So, if you are a young man considering physics as a profession, the criterion should be, not the probable demand for physicists, nor the salary, but the challenge of the job. If you cannot get a thrill out of the anticipation of solving some of the difficult problems which physics presents, you should think twice before entering its portals.

REMUNERATION

I have placed salary second, but it is by no means to be ignored. Want is one of our most useful incentives. It is a mainspring of daily life, whose constant pressure keeps us going through days of monotony and failure. Frail human courage needs this spur. Complete freedom from want would be a doubtful blessing.

What pay can the industrial physicist expect? On a relative basis this question is easy to answer: the pay will be essentially the same as he would receive in any other job that utilizes

the same qualifications, namely, in a university job, whether teaching or research, or in other branches of science and engineering. Several agencies are at work to insure this result:

First, between the industries and universities there is a continual interchange of research men in both directions and at all levels. Supply and demand operate to keep the salary scales comparable in these two competitive markets for physicists. This natural process takes due account of factors affecting the desirability of the job, such as vacations, pleasant working conditions and stability of employment. A small company with uncertain future should and does bid higher for good talent than an established firm or a college with a guaranteed tenure. The dignity and esteem of the college position is also a factor, which makes some small college jobs more attractive than industrial jobs at comparable salary. In the past, there have been more physicists in university work than in industry, so that the opportunity for interchange has sometimes been limited. This will be remedied if the expected increase in industrial research materializes.

Second, within a single laboratory, all the men, irrespective of subject, are arranged in a single rating list in order of merit. This is the practice in our laboratory, and I believe a similar procedure is followed in others. The rating takes into account as many factors as possible, for example: knowledge, initiative, co-operation, leadership. It does not determine the salary level, but aims to assure that the men are in the right order as regards salary, that is, that no physicist of greater merit is below another physicist, chemist or metallurgist of less merit. The list is reviewed and revised twice each year.

Third, within a given industry, careful comparisons are made between the salary scales for research and engineering, with the object of assuring that they shall be the same for equal ability. It is, of course, difficult to compare dissimilar

jobs, but the errors will be those of judgment, and not any preferential rating of one profession over another.

The discussion thus far refers only to relative salaries among members of the same professional class. This is what counts most; in fact, it is the only thing that counts so far as happiness is concerned. The salary must be adequate for your scale of living, which is determined principally by that of your friends; and these will, in general, be your peers, people of similar professional tastes. You must be able to do the things that they do, and not be embarrassed by having to live differently.

The relation of the physicist's salary to that of other groups, on the other hand, is not important, unless one has abilities in more than one field, so that it is necessary to make a choice. In such a decision the choice should be weighted heavily on the side of congeniality of the work, as I have already emphasized. The relative salaries of different groups may vary widely from time to time, according to demand. In the postwar world, the salaries of miners may be higher than those of physicists. If this result comes about naturally, that is, if the higher salary is necessary in order to induce men to enter the mining profession, then it will be accepted by everyone as fitting and proper. If it should result from political pressure, physicists will disregard it, considering it an example of probability-fluctuation in an ever-present phenomenon.

Finally, the actual level of salary is not of critical importance provided it is safely above subsistence, as is true for all groups in this country by a large margin. Certainly there is no close correlation between salary level and happiness.

The point of this discussion is advice to a young physicist, or one who is considering physics, not to be influenced too much by what he hears about salaries in different professions. It is probable that in the lines for which he is qualified they

are not very different, and they are not of primary importance. Love of the work, and natural fitness for it, are the real criterions. It is better to be a good machinist than a poor physicist. Many a young man has been ruined by going to college; that is, his college degree made him unwilling to do the kind of job which he could do well. Other men have been tempted to enter uncongenial careers because of salary considerations. For example, a young man, fresh from an engineering school, came to our laboratory about 1926. It was the period when money was made easily and young men's heads were turned by the demand for their services. He was frankly critical of our salary scale, and announced that he had no intention of working for such wages. He had observed that young men in the commercial branch appeared to rise faster, and he proposed to enter that field. Fortunately, the General Electric Company was offering courses in business administration to its young employees, the first course being one in accounting. This he decided to take. His distaste for it grew, and at the end of the year he hated it so much that he said no conceivable salary could tempt him to enter a business career. From that day he has been happy in his research work, and very successful. This example should not be construed as indicating that physics is a better profession than accounting; that is not true; but that the choice should be made on the basis of love of the work rather than salary. A man can be happy on any salary, within wide limits, provided his friends are in the same boat. But he cannot be happy in an uncongenial profession.

DEMAND

More important than salary is the question of getting a job. What will be the demand for physicists in industry? Can

they get jobs? This is a pertinent question, since many good physicists today can remember the time when the demand for their services was very low. That was an abnormal time, a period of financial crisis and social reform. In discussing future demand, such periods must be treated as exceptional. They should not be disregarded, however. They will come again. Any progressive society must make mistakes, and industrial dislocations are sure to follow. The seriousness of this problem is sufficient to justify putting it at the head of our discussion about demand.

A scientific approach to the problem of dealing with such abnormal periods would be to expect them, to discount them in advance on the basis of their probability and to provide against their impact. This is the method used in experimental physics. In vacuum-tube research, for instance, the experienced physicist knows from statistics that some unexpected accident will happen, on the average, to two tubes out of three. He makes the proper allowances in cost and time schedules, and is able then, not only to be unperturbed by the accidents, but to view them as assets, from which valuable lessons may be learned. The bad tubes are not tragedies; they are part of the job, expected and discounted in advance. In the same way, society should insure itself in advance, during its seven years of plenty, for the seven lean years, or whatever number an actuarial calculation predicts. An effort in this direction was under discussion at the time the war broke out, in the form of a special fund, earmarked for research, to be built up during normal years and used to keep research going during depressions. It is easy to see difficulties in carrying out such a program, but it is well to remember the rule of research, that a solution does not have to be perfect in order to constitute a step in advance. The coverage should preferably be broadened to include engineering and perhaps other fields; for it is socially impractical to keep

one group busy while another group of comparable training is idle. Some provision should be made, however, for the difference in risk between research and engineering. It has happened in the past, and will undoubtedly be true in the future, that research becomes a luxury item for many industries when depressions come. An industry must retain a fair complement of engineers in order to carry on at all; but research, a long-term gamble, can be dispensed with temporarily.

We turn now from the consideration of depressions to that of normal periods, and attempt to answer the question, What will be the *normal* demand for industrial physicists? There are several reasons for believing that the demand will exceed the supply for many years to come. In the first place, physics occupies a position in this war similar to that of chemistry in the first world war, and hence may expect a postwar popularity comparable to that which chemistry has enjoyed in the past two decades. In fact, there is reason for expecting that the increased demand in the case of physics will be even greater than in that of chemistry, in proportion as physicists were less known. It is a rare occurrence that a census taker has ever heard of a physicist, and the task of explaining is such that one is often tempted to register as a chemist.

In the second place, the demand will be helped by the greater employability of the physicist himself, that is, his better attitude toward industrial work, gained as a result of our co-operative war effort. The reputation of physicists in industry has suffered, in the past, from a frequent attitude of superior knowledge – perhaps the expression of an actual inferiority complex, due to lack of familiarity with industrial life. Young physicists are reported frequently to have begun – and sometimes ended – their industrial careers by telling the factory manager just how to run his plant. It is desirable

that such mistakes should be prevented in the future, for the best stimulus to demand is satisfactory performance. What is needed, of course, is a proper respect for the other fellow, a recognition that the engineer, the mechanic, the executive, the accountant, the salesman, each has a job just as important as that of the physicist, and generally knows how to do it much better than a physicist could tell him. The first step toward such understanding is acquaintance, which might be accomplished by more frequent interchanges between university and industrial physicists; for example, a freer flow of teachers into industry and vice versa, nonresident college lectures by industrial men and leaves of absence for teachers to be spent in industrial laboratories. Such a program would help industry evaluate the physicist. Physicists are more useful than has been realized, and better and more versatile than they themselves knew. The nuclear physicist has found that he can "convert" to electronics in a few months. Teachers are discovering that they have executive ability, and many will be available after the war as directors of laboratories.

A third factor in the demand situation is a growing public recognition of the *need for research* as evidenced, for example, by the "Bill to Mobilize the Scientific and Technical Resources of the Nation" now before Congress. This bill may be viewed either with alarm, because of its faults, or with welcome, as a call to action. I prefer the positive view. The bill undoubtedly is faulty; that can be changed. But the public interest is something that will remain, and should be heeded. It is the voice of society, saying, "We want more research." Physicists should welcome this call. They want to do more research. How to finance and manage it is a difficult problem, as always, but a way *can* be found. The interest shown by the public is an implicit demand that science, industry and government get together and find a way. I am confident that our physicists will respond to this call.

One word of caution is needed: we should not expect this expansion of research to happen overnight; growth is a gradual process. An expenditure of a billion dollars a year for research is not too much to look forward to, but if a tenth of this amount were available next year, it is very doubtful that it could be spent wisely. There aren't enough good scientists to use it. In the words of a prominent industrial executive, "The limit of our growth will not be money, but the number of qualified men who can be found."

It is also well to remember that something could be lost by hasty action. The fine spirit of co-operation among scientific men is unequalled in any other class of workers or in any other period of history. This spirit might be injured if science were made a political football or if the direction of research were saddled with a political hierachy.

VALUE OF RESEARCH TO INDUSTRY

If science is to escape political control, industry must respond to the demand for research with a greatly increased program. Can industry afford to do this? Will industrial research pay? The answer to this question depends to a considerable extent on what happens to our patent laws. The opinion is general that research has paid in the past, though no figures are available to prove it. There is even greater agreement on the answer to the negative form of this question: Can industry afford not to do research? The answer is "No." Research is coming to be looked upon as an industrial vitamin, without which an industry becomes decadent and its products obsolescent. Therefore, I think there will continue to be industrial research and an increasing amount of it, whatever the laws.

This will certainly be true of the type of research done in

industrial laboratories, namely, product-improvement. Such work is part of the industrial physicist's job, in many cases the largest part. Let no physicist who has found a useful and interesting place in this type of work feel that it is beneath his dignity, or that he should be doing something more important. Any operation, however commonplace, becomes an important job for the physicist when it needs his services. For instance, the most important current problem in vacuum-tube construction is not the sealing of metal to glass, but the vacuum-tight soldering of metal to metal. Thus, soldering, a plumber's art of yesterday, is today a number one priority job of physicists.

Perhaps "important" is not the right word to describe the feeling, on the part of some young physicists, to which I refer, and which I respect. It is a feeling that they ought to be doing something which makes use of what they have learned in the graduate school. To anyone who is worried about this, I would say that this feeling will soon change. He will find that the knowledge represented by graduate study is a small part of what is needed to make a good physicist. I rate graduate study in physics very high, but not for its factual content. It is rather the attitude, caught more than taught, that is important. It embraces scientific honesty, self-discipline, the habit of scientific reading, belief in fundamental principles, self-confidence in one's ability to get to the bottom of any problem, an absorbing love of the job that makes work play, the mysterious metamorphosis that turns the student into a physicist. I suspect that a similar miracle happens to any young man who is trained under a master, in whatever field. To one who has experienced this miracle, no task is either too hard or too trivial.

Next to product-improvement, the principle type of industrial research is the development of new products. Here the case for profitableness is not so clear. Pioneer develop-

ment is very expensive. For example, the General Electric Company spent several million dollars on the development of the mercury turbine before a single successful turbine was built. It is also a gamble. The success of the mercury turbine venture was in doubt up to the very end. Hence it is not surprising that many companies are cautious about undertaking this type of research. One frequently hears that "it is better to let someone else lose his shirt in pioneer effort, and enter the field later, when the success of the product is assured." The only deterrent to this procedure, other than a possible shortage of pioneers, is patents, and it has been suggested recently that the patent law should be modified, so as to give these late-comers a chance. It is for just this reason that a patent law is needed, namely, to protect the pioneer who is willing to risk "losing his shirt," so that we may continue to have such pioneering.

Not that there would be no pioneer development at all, if the patent law were repealed. There is another kind of protection, namely, secrecy, which could be used to safeguard investment. It is so used today by certain industries, such as the photographic film industry and some chemical industries, whose products are hard to protect by patents. But not all products are amendable to secrecy; it would be hard to keep a mercury turbine secret. Even if it were possible, no one, I think, would consider the substitution of secrecy for patent protection to be a change for the better. Certainly, scientists would view such a change as a calamity, since it would substitute locked doors for the excellent cooperation that is so great an asset of science today.

The third alternative, namely, government-financed development of new products, though necessary in war, is so un-American as to be unthinkable in peacetime. For it is just in this field of new developments that private initiative is most efficient; while government, though an effective agent for



A metallurgist calibrates thermocouples, the instruments used to determine temperature.

(U. S. STEEL CORPORATION)

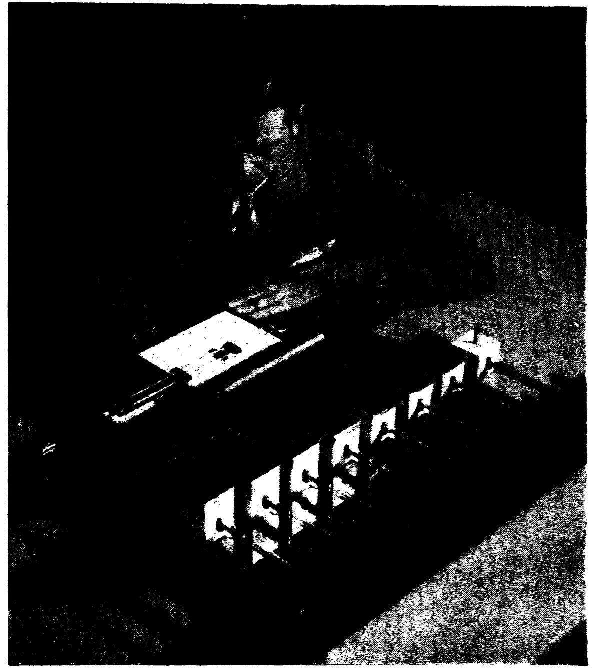


Research engineer makes tensile test of a piece of steel, watching dials which indicate stress applied to the specimen.

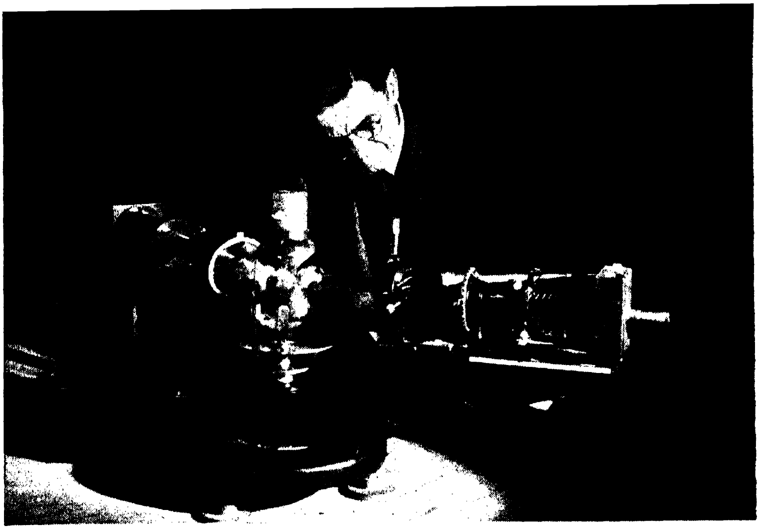
(U. S. STEEL CORPORATION)



R... ...h physicist uses evacuated bell jar, in which thi... ...s of various substances are deposited on metal surfac...
(... TELEPHONE LA... TORIES)



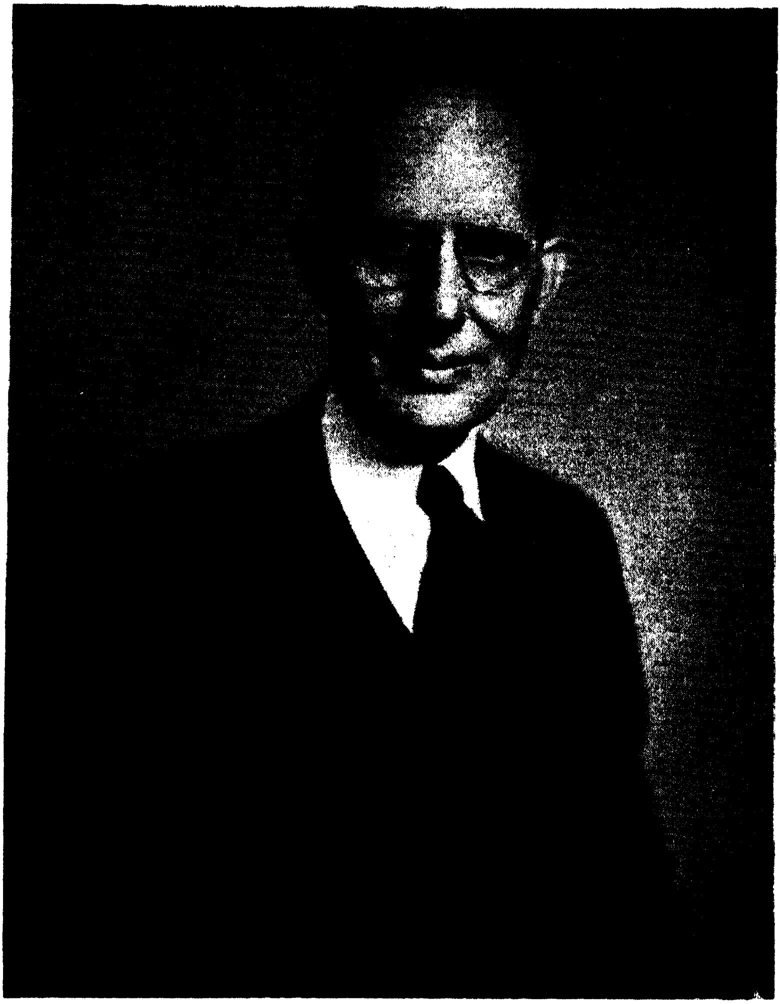
Research physicist using mechanical analog, developed for study of hysteresis, useful in fundamental research in the theory of magnetic and microphonic action. (BELL TELEPHONE LABORATORIES)



Crystal research engineer uses apparatus to aid in study of optical properties of alkali metals used in photoelectric cells, part of research on various phases of television. (BELL TELEPHONE LABORATORIES)



[illegible]gineering: Welding one of the electrodes [illegible] experimental vacuum tube laboratory.
(BELL [illegible] LABORATORIES)



Charles F. Kettering, Vice President of General Motors and Directing Head, General Motors Research Laboratories. "There will always be a frontier where there is an open mind and a willing hand."

(GENERAL MOTORS — PHOTO BY BLANK & STOLLER, INC.)

furnishing common services that have become standardized, is very unsuited to operations which require initiative and judgment.

Therefore, it is desirable that incentives of some kind be found, whether of the type offered by our present patent law or of some other form, which will result in an increased rate of development of new products by industry. Physicists should have an important part in this developmental work.

The two kinds of research that we have been considering, improvement of products and development of new products, are the obvious responsibility of industry. Pure research, on the other hand, that is, research whose aim is to obtain knowledge rather than make something, has generally been done in endowed or state-supported institutions. Such research is a proper public expenditure, since its benefits go to everybody, even transcending national boundaries. It is the one field in which international co-operation is already a reality.

Whether industry can afford to have a share in this pure research is an unanswered question. I am one of those who believe that it can. For one thing, it should do a certain amount as a contribution to knowledge, in partial payment to society for the values it receives from the research of others. In addition, there are benefits to be expected, of two kinds. The first and most obvious is inventions. New discoveries lead to new and unexpected applications, which may be epoch-making. The gamble is big, but the stakes are high. The second benefit is the stimulus which pure research can give to development and engineering. In the co-operation of many departments, each gives and receives, and the gain is mutual and large.

The gain from co-operation is greater than is realized, even by those who prize it most. I talked recently to a young metallurgist who had worked for a year in our laboratory, while taking the "advanced course" at General Electric, and then had gone to a smaller laboratory. "My work is very

interesting," he said, "but you have no idea how helpless one feels out there. A few other technical men are there, but no one to whom I can talk about my problems." This remark is typical; I have heard it often from other men in small laboratories. It can happen even in a large laboratory. It emphasizes the need and value of co-operative group effort.

A couple of everyday examples will illustrate this. In one of our war jobs we needed some means of air-conditioning a metal mercury-vapor tube. The tube operated at 200°C, and there was needed an insulated wire winding and a non-metallic housing cylinder that would stand this temperature. Glass-insulated wire was obtained from one of the factory departments, and was impregnated with a new high temperature silicone varnish by our chemists, who also furnished us with sheet silicone for the housing. In two weeks the problem was solved. On another job some sheet Invar was needed. One of our metallurgists was able to provide curves that showed the correct composition for our purpose. Another metallurgist agreed to melt a 40-lb. ingot in his induction furnace the next morning, and deliver it that same day to the factory forge shop for forging. Following this, it was rolled to the desired thickness in our laboratory metal-working department, spun into form in the machine shop and incorporated in a tube, all within two weeks. There was no haste about these jobs. They were not "rush" projects, but just everyday problems. Two points are to be emphasized in this matter of co-operation. The first is the advantage of having grouped together in a laboratory such a wide range of specialists that expert help can be obtained on any problem which arises. The second, and more important, is the willingness of these departments and individuals to co-operate. This is a precious thing, easily lost, but slow of growth. Like Portia's quality of mercy, it "is not strained." It could not

be obtained, for example, in a government laboratory by passing a law.

This brings us to the main point of our discussion, namely, What kind of industrial laboratories are wanted? Is it undesirable in a democracy to have good industrial laboratories? We have been told by no less a person than the Vice President of the United States that, if there are to be any large laboratories, they should be government laboratories, otherwise they monopolize research and make it hard for the little fellow to compete. I am going to suggest an alternative solution: that the little fellows increase their efficiency, by getting together and co-operating, so that they will be able to compete. Any large company, ours, for example, is usually a group of small companies or departments, whose dealings with one another are on a strict accounting basis, and each must balance its own ledger. The lines of work of the different departments in the General Electric Company cover a wide range, from vacuum tubes to superchargers. Yet these diverse departments support a common laboratory. I will not say that they have solved the problem of how to divide the expense, but they have been able to carry on for forty years. Similarly, any group of small companies, not necessarily making the same product, could combine on research. The only requirements are the will to carry on research, co-operatively, and patience to wait for growth. An appropriation of money does not make a laboratory, nor does a building or even a group of men. A laboratory is a living thing, with a heart and nerves and habits and ideals.

NEED FOR RESEARCH

We come now to the last and all-important question: Of what use is research to society? Is it just a fad? Much has

been written about the amazing new devices and products that science will produce after the war. The effect of these predictions is dazzling and confusing. One gets the feeling that it will be necessary to run as fast as possible just to keep up with the show. Such a view of the future can do no good, and it is not even a true picture. Science can do all these things and much more, but they will not be done tomorrow. The future will begin just where the past left off, with frail humanity plodding along and making progress one step at a time. In the midst of these dazzling predictions we may keep our feet on the ground, even though our ideals reach the sky. As someone has said, "Hitch your wagon to a star, but watch the traffic signs." Therefore, instead of predicting the new products of science, I prefer to consider its problems. These are, of course, the old problems of humanity, which have always existed. What is new today is the will to solve them, and that is our opportunity.

The most immediate need of the world is food and shelter. If physical science can serve this need, it should be our foremost problem. We shan't be able to solve the problem completely; the world will be hungry and ill-housed for many years to come. But American scientists may contribute toward the solution.

For example, farm machinery has had very little research, especially small-farm machinery. The present plough was designed some two hundred years ago, and today its action in exposing the soil to erosion is being criticized. The usefulness of the cultivator and hoe has been questioned recently. The possibility of covering up the soil, as a method of dealing simultaneously with weeds, insects, evaporation and erosion, is being discussed; it offers an interesting field for research, and a possible market for durable plastic sheeting. Plant vitamins and germination accelerators offer good research prospects.

Food processing is crying for research, especially methods of concentrating foods that will allow compact storage, without danger of spoiling or loss of vitamins and flavor. This is a problem for physicists and chemists, more than for agronomists.

Electrification of farms is a field for study in economical power distribution to small customers. Weather forecasting, as a science, is just beginning, and is important for agriculture as well as aviation. Long-range weather forecast is not beyond possibility. Both electrification and weather forecasting are problems for the physicist.

The housing problem is even more in need of research than farming. Wooden houses today are built precisely as in Colonial days, brick houses the same as in Pharaoh's time. New methods and materials should have been found by research, to offset the steady rise in wages and material prices. Since this was not done, the cost of building has more than doubled since 1900. In 1937 the American public spent six billion dollars on building. Half of this, three billion dollars, represents an increase that is chargeable to the unprogressiveness of the building industry.

Compare this record with that of an industry which has carried on continuous research during this period, the electrical industry. In 1940, Dr. W. D. Coolidge, director of the Research Laboratory of the General Electric Company, testifying before the Temporary National Economic Committee, said:

> The United States public paid about $90,000,000 for the lamps it bought in 1938. If it had to buy the carbon lamps of 1900 to produce the same amount of light, its lamp bill would have been increased by about $600,000,000 for that one year, $2,000,000 per working day. That is a small part of the story. The lamps of 1938 through research were so much more efficient than those of 1900 that to produce with the latter

lamps the amount of light used in 1938 would have raised the public's electric light bill for the same year by about $3,000,-000,000, or $10,000,000 per working day. Thus research on lamps has given the public an annual saving of about $3,500,-000,000, more than the cost of all the private automobiles sold in 1938 in the United States. But even this is only part of the story. The foregoing was calculated on the basis of average power rates for electric lighting in 1938. The average cost of power today is less than one-third of what it was in 1900, and in this reduction research has played its part. If the light used in 1938 had been produced by the lamps of 1900 with the electric power rates of 1900, the cost would have exceeded that of 1938 by over $10,000,000,000—$30,000,000 per day. Of course, the public would get along with less light for they could not have afforded such a lighting bill. What that would have meant in reduced safety and efficiency in industry, in reduced safety on streets and highways, and reduced comfort and convenience in the home cannot be evaluated in dollars.

Similarly difficult to evaluate in terms of money saved are the new electrical products, such as X-rays, refrigerators, radio, which benefitted mankind and gave employment to hundreds of thousands. But the addition of a single small unit may be used as a yardstick. The screen-grid tube is an example. Radio receivers once were made without it, and could be now, but they would require twice as many tubes and circuit elements, and would cost twice as much. The American people spent 400 million dollars for radio receivers in 1941. Without screen-grid tubes, the cost would have been double that value. Hence, the screen-grid tube saves the public 400 million dollars a year. These savings are the result of research work by the electrical industry, and are cited as a basis for gauging what other industries, such as building, may be expected to accomplish by research in the future.

Next to food and shelter, the greatest need of the American people is the opportunity to work. The problem sounds

simple. We have plenty of factories of the right kinds, and we have people who want to work and are willing to spend all that they earn, buying the things which they, collectively, make. The cycle of earning and buying obviously closes at any level of employment, that is, whether the employment is 100 per cent or only a small fraction. Of course the problem is complicated by the durable or equipment goods, which are bought by corporations rather than individuals. Evidently it isn't simple, as our experience during the last ten years has proved. It will not be solved by a stroke of genius or of luck, but only by a long series of small steps.

In the meantime, physical science can provide a tonic for this employment ill. The tonic is new products. New products are resistant to depression psychology, and experience has shown that they can be sold when old products cannot. In this way, physicists can contribute to the all-important job situation.

Finally, there is something more important than food and shelter and jobs. These alone cannot give happiness. In fact, they have very little relation to it. The More Abundant Life does not consist of things. In proportion as happiness is more important than physical comfort, so psychology and philosophy and religion are potentially more important than physical science. We may hope that they will some day shed more light on the great problem of human happiness. In the meantime, it is the privilege of physicists to contribute toward a happier world, first by finding pleasure in scientific accomplishment, and second, by helping others and by finding pleasure in the accomplishments of others; that is, by true co-operation.

HOW CAN WE DEVELOP INVENTORS?

By Charles F. Kettering

Vice President and Director of Research,
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I think this question of how can we develop inventors, or inventions, because that is the real problem, is one that should concern us greatly. There are many different ideas of what an invention is. The inventor has one idea, the manufacturer has a different one, and the patent attorney has still another. Sometimes it takes quite a high order of intelligence to detect any similarity between them. I mean this seriously – it is a common thing for an inventor not to understand the patent on his own invention.

Likewise, there is no sharp line of demarcation between invention and research except for this distinction: that invention has to do with a specific result, while research is concerned with the determination of those factors which may be necessary in the development of that result.

Some years ago a survey was made in which it was shown that if a person had an engineering or scientific education, the probability of his making an invention was only about half as great as if he did not have that specialized training.

Now that is very interesting, and I have spent a great deal of time wondering why it is so. As a result, I have arrived at a definition of what an inventor is. An inventor is simply a fellow who doesn't take his education too seriously.

You see, from the time a boy is six years old until he graduates from college he has to take three or four examinations a year. If he flunks once, he is out. But an inventor is almost

always failing. He tries and fails maybe a thousand times. If he succeeds once, he is in. These two things are diametrically opposite.

We often say that the biggest job we have is to teach a newly hired boy how to fail intelligently. We have to train him to experiment over and over and to keep on trying and failing until he finally learns what will work.

We also have to teach him that everything is not in the books. In his education he invariably gets the idea that this is so because his textbook is always the last word and final authority on whatever he is studying. If we fail to do this, sooner or later he will say, "There is no sense trying this experiment because Page 284 of this book says it won't work."

Then we have to explain that these things we are doing have never been done before. If they had, we wouldn't go to all the trouble of repeating them. The books used to say we couldn't build a Diesel injector to operate at 20,000 pounds per square inch. What it really meant is that an injector couldn't operate at that pressure if it was built as the book specified. Today we have hundreds of thousands of injectors operating at pressures much higher than that. The point is simply that, no matter what we are doing, if it is new we can always find a book that will tell us it can't be done. Any time we want to stop a project, all we need to do is assemble a committee and tell them about it. Immediately they will tell us we were crazy to start it. So to protect ourselves we have made this very simple rule: when you start a new problem, stay away from the library because it may handicap your thinking.

In training an inventor, how closely do we want him to work with the library? Should he see what has been done first, or should he start out with his own ideas and then go back to the books after he has got a little way along?

The first step is always to set up the problem. When we

have done that, we say, "Here's the way we think we ought to proceed," and then go to the library to see what others before us have thought about it. But if we go to the library first, few of us are strong enough to stay out of the rut that may be set up. So another thing we must do in developing an inventor is to teach him to analyze his problem. If he decides that it is worth working on at all, what is the probable first experiment he should try?

Many people want to go beyond the first experiment in their predictions. "If this experiment works," they say, "we will do such and such next." But we should not worry about that. If we knew what was going to happen, we wouldn't need to experiment in the first place. We should realize that prior to the first experiment our ignorance factor may be as much as 100 per cent.

"But suppose the experiment doesn't work the way we think it should?" they ask us.

The chances are ten to one it won't. That shouldn't deter us, however, from going ahead and trying it. After all, an experiment that fails is simply an experiment in which we are wrong. Rarely does an experiment mislead us, providing we are intelligent enough to follow as it directs.

If an experiment doesn't work the first time, it must be tried again; and when a successful experiment is obtained, a continuity can be laid out for going on to the next step. We will then decide what the second experiment should be and go through with it in exactly the same manner. Since none of us is ever smart enough to arrive directly at the final result, we must work our way very laboriously from experiment to experiment and from test to test until we finally get there.

A lot of people don't want to do this. They would like to find a short cut for the tedious trying and failing of experimentation. They think they are smart enough or educated

enough to get the result directly. Unfortunately, the only people who have ever accomplished anything in science or engineering are the ones who never thought they were smart enough to get irked by having to try things to see if they would work.

A man who had seen a test of one of our Diesel engines came in to see me the other day. "That is a very efficient engine," he said. "I would like to talk to your thermodynamics expert about it."

"I am sorry," I replied, "we don't have anyone here who even understands the word 'thermodynamics,' much less be an expert on it. But if you want to know how we developed this engine, I'll be glad to show you."

I took him to our dynamometer room and showed him our single-cylinder set-up and told him how we had tried one thing after another for about six years until the engine itself finally told us exactly what it wanted.

"Goodness," he said, "that's an awfully tedious way to design an engine."

"It is," I agreed, "but it is the only way we know."

We don't know how to do any new job without going through all that tedious cut-and-try. Therefore, the next thing we must tell these young engineers is that tediousness is something they must endure and not resent even though they have a technical education.

These things seem extremely simple, but they are basic to the problem of developing engineers.

The point is that we don't solve a technical problem or make an invention in the laboratory. We do these things in our heads. All this laboratory apparatus is simply to help us get an understanding of the problem we are working on. I think the thickness and density of the human skull can be very well represented by the amount of apparatus we sometimes need simply to force an idea through a quarter inch

of skull bone. That is why it is so important that we develop proper attitudes in the people we are training to be inventors.

About ten years ago we started a new study of the strength of materials which was based entirely on testing a production piece under simulated working conditions. In other words, if we were interested in a crankshaft, we would build a testing machine that would load that crankshaft exactly as it is loaded in the engine; that is, a load fluctuating so fast with so much tension, so much torsion, at such a temperature, etc. We did that because we had learned that tests on standard test specimens gave us information of a very unsatisfactory kind and that when we tried to test a piece to failure in an actual engine the resulting debris was such that we couldn't tell just what had happened.

In our machine we put anticipators on a piece so that the instant a failure started the load would be released automatically and we could see exactly where the trouble had started.

With this machine we have been able to improve the fatigue life of many mechanisms as much as 500 per cent simply by seeing *how* and *why* the failure starts and by then making very small changes in fillets or slight shifts in temperature during heat treatment.

We couldn't have calculated these things. No one is smart enough to make such calculations. It has to be a very primitive sort of study which goes back to the very elementary process of trying a thing, learning its weaknesses, and then trying something else.

One of the problems which a research laboratory will always have is how to get along with the manufacturing end of the particular organization to which it belongs. The production man has a problem, and he brings it to us to solve. We analyze it and write a report on our solution. If we use a lot of logarithmic curves and fancy nomenclature the production man never heard of before, he gets mad because he

can't see that we have helped him very much. I don't blame him.

To avoid that difficulty, we have worked out a very simple procedure. Before a special report is distributed, it is carefully read by someone in our organization who knows the person for whom the report is intended, and a little circle, or goose egg, is drawn around every word that he thinks may be misunderstood. Then we call in the research engineer and ask him to read the report aloud – but skipping the words that are circled. He starts reading and then exclaims, "My goodness, if you are going to leave out all those words, it won't make any sense at all!"

"All right," we say, "perhaps the reader won't understand those words, so it is just the same to him as if they weren't there at all. If we are going to help with this problem, we must use words that will be understood."

One of these reports had to do with noise and the word "decibel" appeared several times on every page. The boys couldn't find a simpler word for decibel, so with every copy of that report we supplied a little noise box that had ten keys on it. If the report said the noise level was seven decibels, the reader just punched the key marked "seven" and he could hear exactly what seven decibels of noise was.

This question of words and the meanings that we attach to words has always been very interesting to me. It is like the formula problem in which if a fellow knows the formula for something, he thinks he understands all about it. A lot of people think that if they know the name of something, that's the whole story.

As an illustration, I once asked a famous scientist this question: "Why can I see through a pane of glass?"

"That's very simple," he said. "Glass is transparent."

"I'm afraid the word 'transparent' means nothing at all to me," I replied.

"The word 'transparent' simply means anything you can see through," he said. "Why do you want to know that?"

"I would like to know *why* I can see through a pane of glass. I would like to know whether light waves travel through the glass as light rays – or whether they are received and rebroadcast in some other form from molecule to molecule. If I knew that, I would be better able to decide some other things I would like to know."

"The trouble with you," he said, "is that you are a modelist. You want an image of something. Modern science doesn't form images any more. We stopped that a hundred years ago. Give me a better problem–something a little more practical."

"All right, here's one: when I rub my hands together, why do they get warm? Why shouldn't they get cold?"

"Oh, that is quite simple – it is due to friction."

"Yes," I said, "now what is friction?"

So we argued back and forth for three quarters of an hour and finally we came to the profound conclusion that we don't know anything about friction – except that friction is a thing that makes your hands warm when you rub them together – and we don't even know how it does that.

A few years ago I assigned a young man to work on this friction problem and had him rub little pieces of metal to see how much they wore away, how much heat they generated, and so on. After he had been working on this problem for a little while, I stopped in to see him. "How are you coming along?" I asked.

"Not very well," he replied. "Don't you think this is an awfully childish problem for a fellow who has the kind of education I have?"

I didn't think so, or I wouldn't have assigned him to it, so I asked what the trouble was.

"It wouldn't be so bad," he exclaimed, "if it wasn't all in the books."

"I'm glad you mentioned that," I said, "because if we have you working on this thing when it's all in the books, like you say, then we ought to stop right away. But before we do that, I want you to show me that book. If you can find that book or any book like it, I will give you a medal."

I saw him about a month later and asked how he was progressing on the medal business.

"Awful," he said, "I haven't been able to find anything. And I can't understand that, because it's something so fundamental I should think a lot would be known about it. I can't understand it at all. There's not a thing in the books about it."

I want to tell you something of the outcome of this episode because it shows how much we can accomplish if we don't place ourselves too high above our jobs. This same young fellow soon discovered some very interesting fundamental facts about friction and wearing surfaces which have enabled us to produce better piston rings for Diesel locomotives than we ever had before. When we first started to run our locomotives, we had to change rings about every 50,000 miles. No one objected to that. They thought 50,000 miles was about as long as a piston ring ought to last. Now we have rings that will last 500,000 miles, and I think we ought to be able to get them to last 1,000,000 miles before we're done.

It was in connection with these same engines that someone once asked how it happened that we were making most of the Diesel-electric locomotives in the country. "You must have awfully good patent protection," he said.

"Well, here's the reason," I said. "You see, a great many people think we're crazy. That is much better protection than any patent."

I would rather have my competitor think I am crazy than have a stack of patents a mile high, because he can easily get around my patents, but if he thinks I am crazy, he won't even bother to check up on them. I was in the automobile

starting, lighting and ignition business for five years without any patent protection at all to speak of, because everyone knew that the breaker mechanism in my ignition system was crazy, and that it wasn't worth copying. They infringed every patent I had, but they didn't infringe my ignorance factor.

I often tell the boys this story: I have been making inventions and taking out patents for many years. When I first began to apply for patents, most of my inventions had been patented 50 or 60 years before. Later I was only 40 years behind – then 30 years – and so on. So I drew a set of coordinates and plotted just how far behind I was on each invention. There was a gentle slope to the curve, so I could extend it to the base line to see how old I would be when I made an original invention. It comes to about 125 years.

If we can succeed in eliminating from a young man's mind the idea that just because he thought of a thing it must be very good, then we can go ahead without the danger of temperament getting into engineering.

We have a little rule in our laboratory which we think solves this problem. It's a very simple rule and the only rule we have. It is just this: "The Job Is the Boss." What does the engineer think of this new piston? That doesn't matter. What does the engine think about it? That matters. The engineer's opinion is worth very little. The engine's opinion is worth a great deal.

If the engine says, "I like this piston," and it happens to be contrary to the engineer's pet idea, that's too bad. It simply proves that the engineer was wrong. After all, as we said, the only reason for all this expensive research is that it corrects our ignorance factor so that we can see the problem in its true light.

Opinions are not the only things that lead us astray. Some-

times we are led into difficulties by certain aspects of the so-called practical side of our educations. We accumulate rules of thumb, arbitrary constants and formulae. We accept these as fundamental. We should question them whenever we encounter them. They are the stumbling blocks of progress.

There is a formula by which we can calculate the fatigue life of a piece of spring steel which is being stressed under certain conditions. This formula tells us how many thousand cycles of stress the spring will undergo if its surface is perfectly mirror-smooth, how many less if it is slightly rough, and how many still less as its roughness increases. We take a flat piece of smooth spring steel about three inches wide and two feet long and put it in a test machine and bend it back and forth until it breaks. We find that the standard spring, as furnished by eight or ten different steel makers, will break in about the same time – at a couple thousand cycles. That checks very closely with the formula. We ask each of the steel makers to run the same test and their results check with ours. The formula and the experiment agree. Everyone thinks that it is a wonderful proof of the formula and shows there is no use trying to run a spring any longer than the formula says. Then we say, "Suppose we bang up this piece of spring steel until it is rough all over – then how long will it last?"

After thinking about this for awhile, they say, "We don't know how many cycles of stress it will stand, but we all agree that its fatigue durability will be seriously impaired."

So we asked them to make us some more samples. "Put a little mark on them so you can identify them as your pieces," we say. Then we give these samples a little treatment which we call shot blasting, or surface peening, in which we shoot a lot of little hard steel balls at each sample until it is thoroughly roughened. That done, we send the samples back to the steel makers to be tested.

Then a surprising thing happens. Instead of breaking at 2,000 cycles, the samples are flexed up to 2,000,000 cycles and still they don't break. The formula still says they will break at 2,000 but they don't know that. They keep right on flexing at 2,000,000. That is quite a gain in per cent.

We have learned that in most problems there is a normal time rate of development which corresponds very closely to the normal yearly increment of improvement made by industry. There is not a great deal that we can do to speed up such improvements, because they are so intimately geared into the whole system that they can be assimilated only at a certain rate. But in other problems, such as certain medical problems, the question of how long it is going to take to solve them is of relatively little importance. The results will justify any expenditure of time. All that is necessary is that the man who is going to work on the problem be shown that it is worth solving, or he won't want to try it.

We had some experience with this in the early days of the ethyl gasoline development. We had been working on the so-called aromatics for a number of years and had some pretty good results, but nothing really exciting. So some of the boys came up to my office and said, "We are young yet, and we would like to do something in the world, and we don't want to be kept on this problem forever, because we don't see any hope of ever working it out."

I was leaving for New York that afternoon, so I said, "Let me have a couple of days to think this over, and when I come back I'll see if I can't work out something for you."

I thought that it would be wrong to stop this work, even though they had been correct when they said our progress to date was very discouraging. When I got on the train to go back to Dayton, I noticed a newspaper lying on the seat beside me and I picked it up. On the first page there was a

little item entitled, "University Professor Discovers Universal Solvent."

That interested me because I happen to know an amusing story about two chemists who were trying to discover a universal solvent. It seemed they talked a banker into loaning them some money and set up a little laboratory just outside of town. One winter morning a farmer had a blow-out outside their place, so he came in and asked if he could use their telephone to call up the garage. They said, "Sure, go right ahead." When he was through telephoning, he asked if he could wait there until the garage brought him a spare tire and they said, "Sure, you can." So he stood there watching them for a while, and finally he asked what they were doing.

"We are working on the most important thing in the world," they said. "We are developing a universal solvent."

"What does that mean?" asked the farmer.

"Well, that is a liquid that will dissolve anything you put into it."

"My goodness," said the farmer, "that is marvelous, but what in tarnation are you going to keep *it* in?"

Because I happened to know that story, I was interested in this universal solvent and I read the newspaper story in its entirety. The material referred to was selenium oxychloride.

The next morning when I got to the laboratory I showed this newspaper item to the boys and said, "Here's one we'd better try before we quit," so they went ahead and got some. It turned out to be almost a universal solvent, but it did something that none of us had anticipated. Theoretically, selenium oxychloride should have made the knock worse because it contained both chlorine and oxygen, which had been knock inducers in every other compound we had tested. But instead of inducing knock, selenium oxychloride turned out to be a powerful knock suppressor. That was our first

step into the study of the metallo-organic compounds, which led us through a great many experiments until we finally arrived at tetraethyl lead.

The point of this story is that we must always know whether a problem is worth solving. There will always be dark days, but if your conviction of the value of the problem is such that you go right ahead in spite of the difficulties, the chances are that you will achieve success in the end.

I like to think that we can take even a highly educated young man and teach him to be an inventor without ruining his education. I have only one complaint against our educators and it is that they haven't always told us the complete story.

A friend of mine who teaches general medicine at one of our large universities once told me this story about education. He is an old hand at teaching medicine. He lectures to the classes, teaching the boys to be general practitioners. His system is sound and doesn't differ radically from similar courses in other universities, except for the last lecture he gives the group. That lecture is unique. On this occasion, he says, in part:

"Young men, we are together for the last time. We have had a very pleasant time. You have been a good class and I have enjoyed working with you.

"I have given you the best information available – the best case histories I could find. The textbooks we have used are the most widely accepted and reliable. But before we part company, I want to caution you that the science of medicine is developing so rapidly that in a few years from now perhaps half of the things I have taught you won't be so. Unfortunately, I don't know what half that will be."

I have been very interested in co-operative education because I feel that by bringing a boy in contact with both the school and industry we can lap-weld him to a job instead

of butt-weld him. I worked with Dean Schneider at Cincinnati for a number of years. I have also been interested in a co-operative system at Antioch; and right before Dean Schneider died, I helped to get him to go out to Northwestern University to set up the co-operative system there.

My interest in co-operative education is not limited to having the boys go to school half time and work in industry half time. I don't care how it is done, but I would like to see the university and industry work closer together because I think they should understand each other's problems. I think if we could do that, it would be much less necessary to teach trade subjects in school. We could spend more time on the fundamental broad principles of physics, chemistry and mechanics.

There are several other ways that this result can be achieved. One is by alternating the professors instead of the students. The instructors could teach half time and, as I once said, work half time. Somebody objected to my saying that, so I apologized, but you know what I mean.

I don't care how we achieve this co-operation, whether it is half-timing the boys or half-timing the instructors, or doing research, just so the educational institutions can teach these boys the fundamentals they will need in their work, and industry can teach them the practical applications it will need from them in that work.

If we can just achieve the broad outlook and be honest with ourselves and admit that the things we know are so small compared with the unknown, I think we will see that there is no end to progress. I am not worried about the libraries we have today – I am worried about those infinitely greater libraries that haven't any books in them yet. Every year is going to add new things and new books that we don't know. I am interested in getting some of those books written.

We should date-line every bit of information we have. We should say, "This is what we know as of today." We shouldn't

worry about what it was yesterday – or what it is going to be tomorrow. We should recognize that ideas change and grow, and we should gear ourselves to the most progressive thinking. If we can do that successfully, we will have no difficulty in teaching men to become inventors, because inventing is simply a state of open-mindedness.

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